CAMERON HYDRAULIC DATA

SPEC. GR. H_2O - P. 25

$$\frac{\text{lbs } H_2O}{\text{HR}} \div 500 = \text{GPM}$$

Presented to

[redacted]

[redacted] JUL 07 1977

Compliments of

Ingersoll-Rand Company

$$\text{BHP} = \frac{\text{GPM (PSI DISCH)}}{1714 \text{ (eff \%)}} \quad \text{P. 12}$$

$$\text{BHP} = \frac{\text{GPM (H IN FT) Sp. Grav.}}{3960 \text{ (PUMP EFF } \frac{\%}{100})} \quad \text{P. 12}$$

CAMERON HYDRAULIC DATA

A handy reference on the subjects of hydraulics, steam, and water vapor

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and

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Fourteenth Edition
First Printing

Price $3.00

Ingersoll-Rand Company

Cameron Pump Division

1 Broadway, New York, N. Y. 10004

CONTENTS

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CHAPTER 1

HYDRAULICS

CONTENTS OF CHAPTER 1

Hydraulics

Hydraulics*

Hydraulics is concerned with the behavior of liquids at rest and in motion. The data given in this chapter apply to all true liquids. A liquid has a definite volume as contrasted to a gas which tends to expand indefinitely. When unconfined a liquid seeks the lowest possible level. The surface of a liquid at rest is always perpendicular to the radius of the earth at that point. Due to its fluidity a liquid conforms to whatever shape its container has.

Liquids are said to be "practically" incompressible. This is near enough to the truth at low pressures, but at high pressures there is a slight change in density which should be taken into account.

The pressure existing at any point in a liquid at rest is caused by the atmospheric pressure exerted on the surface, plus the weight of liquid above the point in question. Such pressure is equal in all directions and acts perpendicularly to any surfaces in contact with the liquid.

All liquid pressures can be thought of as being caused by a column of liquid which due to its weight would produce a pressure equivalent to the pressure at the point in question. Such a column of liquid, real or imaginary, is called the "pressure head," or the "static head."

The flow of liquids may be caused by gravity or by mechanical means.

Viscosity

In flowing liquids the existence of internal friction or the internal resistance to relative motion of the fluid particles must be considered. This resistance is called viscosity. It varies greatly from one liquid to another and decreases with rising temperature. For data on the units of viscosity see page 75.

Velocity

Since a liquid is practically incompressible there is a definite relation between the amount flowing past a given point in a given time and the velocity of flow. This relation is expressed thus: $Q = Av$ or

$$v = \frac{.4085 \text{ gpm}}{d^2} = \frac{.2859 \text{ bph}}{d^2}\dagger$$

Pumping

To move a liquid against gravity, as with a pump, work must be expended. A pump may actually raise the liquid, or force it into a pressure vessel or merely give it enough head to overcome pipe friction. No matter what the service required of a pump, all forms of energy imparted to the liquid in performing this service must be accounted for in establishing the work performed. In order that all these forms of energy may be algebraically added it is customary to express them all in terms of head expressed in feet of liquid. The terminology used to define the various types of head is as follows:

*See page 14 for symbols used in this chapter.

†This formula applies only to circular conduits.

Friction head (h_f) is the pressure (in terms of ft of liquid) required to overcome the resistance to flow in pipe and fittings.

Velocity head (h_v) is the vertical distance a body would have to fall to acquire the velocity v. It corresponds to the static or pressure head which would cause that velocity.

$$h_v = \frac{v^2}{2g} = .0155v^2 = \frac{.00259\ \text{gpm}^2}{d^4} = \frac{.00127\text{bph}^2}{d^4}\ \dagger$$

Velocity head may be converted to equivalent pressure head by suitable means such as a Venturi tube. In any flowing liquid the sum of pressure head and velocity head remains constant.

Total static head (h_{ts}) on a pump is the vertical distance (in ft) between the free level of the source of supply and the point of free discharge or the level (or equivalent level) of the free surface of the discharge liquid.

Total suction lift (l_s) is the reading of a mercury column at the suction flange converted to ft of liquid and corrected to the pump centerline** minus the velocity head (in feet) at the point of column attachment.

$(l_s)^* = (l_{ss}) + (h_f \text{ suct})$

Total suction head (h_s) is the reading of a gage at the suction flange converted to feet of liquid and corrected to the pump centerline** plus the velocity head (in ft) at the point of gage attachment.

$(h_s)^* = (h_{ss}) - (h_f \text{ suct})$

Total discharge head (h_d) is the reading of a pressure gage at the discharge flange converted to feet of liquid and corrected to the pump centerline** plus the velocity head (in ft) at the point of gage attachment.

$(h_d)^* = (h_{sd}) + (h_f \text{ disch}) +$ vel. head loss at discharge of system.

Total head (H) is the total discharge head minus the total suction head or plus the total suction lift.

$(H)^* = (h_d) - (h_s)$ or $(H)^* = (h_d) - (l_s)$

Net Positive Suction Head (NPSH)

Liquid can not be sucked into a pump. A positive head must exist in order to push the liquid into the impeller eye. The pump industry has accepted the term "NPSH" or "net positive suction head" to describe this available head at the pump intake.

(a) Net positive suction head (symbol h_{sv}) is the total suction head in feet of liquid absolute, determined at the suction nozzle and corrected to datum, less the vapor pressure of the liquid in feet absolute. Thus:

$h_{sv} = h_{sa} - h_{vpa}$

where

h_{sa} = total suction head in feet absolute

$= h_a + h_s$

or,

$h_{sv} = h_a - h_{vpa} - h_s$

where

h_a = atmospheric pressure in feet absolute

*These formulae apply when estimating before a pump is installed. For use of instruments to determine these data, see page 241.

**On vertical pumps the correction should be made to the eye of the suction impeller.

†Formulae for hv and v involving gpm and bph apply only to circular conduits

h_{vpa} = vapor pressure of liquid in feet absolute
h_s = total suction head feet (positive = $+h_s$)
h_s = total suction lift feet (negative = $-h_s$)

or,

$$h_{sv} = \frac{144}{w}(P_a - P_{vp}) + h_s$$

where

P_a = atmospheric pressure in psia
P_{vp} = vapor pressure in psia
w = specific weight of liquid in pounds per cubic foot

(b) If a hot water pump takes its suction from a source where the prevailing pressure is equivalent to the vapor pressure corresponding to its temperature, the net positive suction head is the difference in elevation between the liquid level and the datum minus the entrance and friction losses in the suction piping.

SUCTION LIMITATIONS

It will be noted that the maximum theoretical dynamic suction lift would be a distance equivalent in ft of liquid to the atmospheric pressure less the head equivalent to the vapor pressure of the liquid, less the head equivalent to the pressure of any gas in solution, less the friction head and less the head equivalent to the entrance loss. Practically, the suction lift that can be handled without cavitation and vibration in the pump is somewhat less than the theoretical. The actual suction lift obtainable depends not only on the above factors but also on the characteristics of the liquid, the total dynamic head and the pump speed, capacity and impeller design.

Specific speed of an impeller is an index to its type and is expressed by the formula

$$\text{Specific Speed } (N_s) = \frac{\text{rpm}}{H^{3/4}}\sqrt{\text{gpm}}$$

It is used when designing impellers to meet different conditions of head capacity and speed. High head impellers usually have low specific speeds while the reverse is true for low head impellers. Values of $H^{3/4}$ and $\sqrt{\text{gpm}}$ are easily found from the curve on page 15.

Suction Limitations—Among the important factors affecting the operation of centrifugal, axial-flow and mixed-flow pumps are the suction conditions. Abnormally high suction lifts usually cause serious reductions in the capacity and efficiency of the pump and often lead to serious troubles from vibration and cavitation.

The specific speed has a direct bearing on the design of impellers for maximum suction lifts without cavitation.

A pump of low speed and consequently low specific speed, will operate safely with a greater suction lift than one of a higher speed. If the suction lift is very high, (over 15 feet for water) it is often necessary to use slower speeds and larger pumps, while with a low suction lift or positive head on the suction, the speed may often be increased and a less expensive pump used.

Increased speeds without proper suction conditions often cause serious trouble from vibration, noise and pitting. Recognizing this fact, the more prominent pump manufacturers have adopted for their guidance several curves representing suction lift in relation to capacity and speed or to specific speed or to temperature.

The curve page 16 applies to pumps handling water at sea level up to 85F temperature. It may be applied approximately for other altitudes, temperatures and liquids by selecting a specific speed that provides a net positive head above suction pressure equivalent to the suction lift and suction head lines shown on the chart.

The curve page 17 applies to condensate pumps. The curve page 18 applies to boiler-feed pumps. This curve will also give approximate results for altitude conditions and for other liquids if the vapor pressure scale instead of the temperature scale is used in selecting the suction head required.

It will be to the purchaser's advantage to buy and operate pumps within the limits indicated by the curves and in line with what has proved to be good practice.

WORK PERFORMED IN PUMPING

In order to determine the work required of a pump it is necessary to know the total dynamic head and the weight of liquid to be pumped in a given time. Usually weight is not given but rather volume in gallons per minute or barrels per hour, along with the density or specific gravity. The weight can be calculated from this information, but this is not necessary since the horsepower formulae are usually given in terms of gpm or bph. Theoretical horsepower of a pump is usually called the hydraulic horsepower.

FT HEAD S.G. FT

$$\text{hyd hp} = \frac{\text{gpm (H) (s) } 8.33}{33{,}000} = \frac{\text{(gpm (H) (s)}}{3960} = \frac{\text{bph (H) (s)}}{5660}$$

PSI PSI

$$\text{hyd hp} = \frac{\text{(gpm) } (H_p)}{1714} = \frac{\text{(bph) } (H_p)}{2450}$$

SG

FT PSI

$$\text{brake hp} = \frac{\text{(gpm) (H) (s)}}{\text{(3960) (pump eff)}} = \frac{\text{(gpm) } (H_p)}{\text{(1714) (eff)}}$$

The actual or brake horsepower of a pump is greater than the theoretical or hydraulic horsepower by the amount of the losses incurred in the pump, through friction leakage, etc. The efficiency of a pump is, therefore, measured as:

$$\text{Pump eff} = \frac{\text{hyd hp}}{\text{brake hp}}$$

Other useful formulae are:

For motor-driven pumps

$$\text{Kw per 1000 gal per hr of liquid} = \frac{.00315 \text{ (s) (H)}}{\text{(pump eff) (motor eff)}}$$

For direct-acting steam pumps

$$\text{Duty in terms of ft-lb per 1000 lb of steam} = \frac{\text{theor hp (1980) 1,000,000}}{\text{total steam in lb/hr.}}$$

Sometimes theoretical hp for figuring duty is calculated using static head instead of total dynamic head. In this case Duty is in terms of ft-lb of useful work done per 1000 lb of steam. As given above the formula is in terms of ft-lb of actual work done per 1000 lb of steam.

FRICTION LOSSES IN PIPE

The loss of head or pressure due to friction, which is experienced when a liquid flows through a pipe, is called the friction head. A vast amount of research has been conducted to determine the amount of friction loss for different conditions.

It has been found that two types of flow may exist in a pipe; the one being variously designated as streamline, laminar or viscous flow, and the other as turbulent flow. For each liquid, and for various viscosities (i.e. temperatures) of the liquid, there is a certain critical velocity for every pipe size, below which the flow is viscous and above which the flow is turbulent. The critical velocity occurs within a range of Reynolds numbers of about 2100 to 3000. Reynolds number, $R = \frac{Dvp}{u}$ (where, D = pipe dia in ft; v = velocity in ft per sec; p = density in lb per cu ft; and u = abs visc in lb per ft sec). In determining friction loss it is common practice to use the value of 2100 as the point at which flow changes from viscous to turbulent. The chief difference between viscous and turbulent flow, as far as the friction loss is concerned, is that in viscous flow roughness of the pipe surface does not affect the friction loss, while in turbulent flow it has a very marked effect. Turbulent flow conditions are usually encountered except when very viscous liquids are being handled.

In this data book tables for the friction loss in pipe have been presented in the chapter on water data and again in the chapter on miscellaneous liquids. The reasons for this apparent duplication are several. First, for water the variation in viscosity and its effect on friction head is relatively small and may be practically neglected. Instead, attention is paid to the kind of pipe used and to the different inside diameters found in commercial pipe classifications. Finally, these tables include in addition to the friction head, the corresponding velocities and velocity heads—information which is often useful. On the other hand, the tables for friction loss in miscellaneous liquids are primarily concerned with the effect of viscosity on the friction head. The data are confined to wrought iron or steel pipe, but they cover both viscous and turbulent flow.

Very accurate information is now available on friction losses through pipe and fittings. The tables in Chapter "3" are based on the latest available information.

For most calculations, however, a considerable factor of safety is desired. It is difficult to determine the exact degree of roughness in new pipe, and even more difficult to estimate its future roughness. Therefore, the accuracy of present-day friction calculations may be misleading under future pipe conditions.

The empirical formulae such as those of Williams and Hazen are familiar to many engineers and for practical use are often more convenient than the Fanning formula and its Reynolds number criteria. For this reason the Williams and Hazen tables have been retained in Chapter "2". If greater accuracy is desired, the tables in Chapter "3" for a viscosity of 31.5 SSU can be used for the friction loss of water in new steel pipes.

Some engineers add 15% to the friction values for new pipe in making flow calculations. This would correspond to a Williams and Hazen coefficient of about C=125.

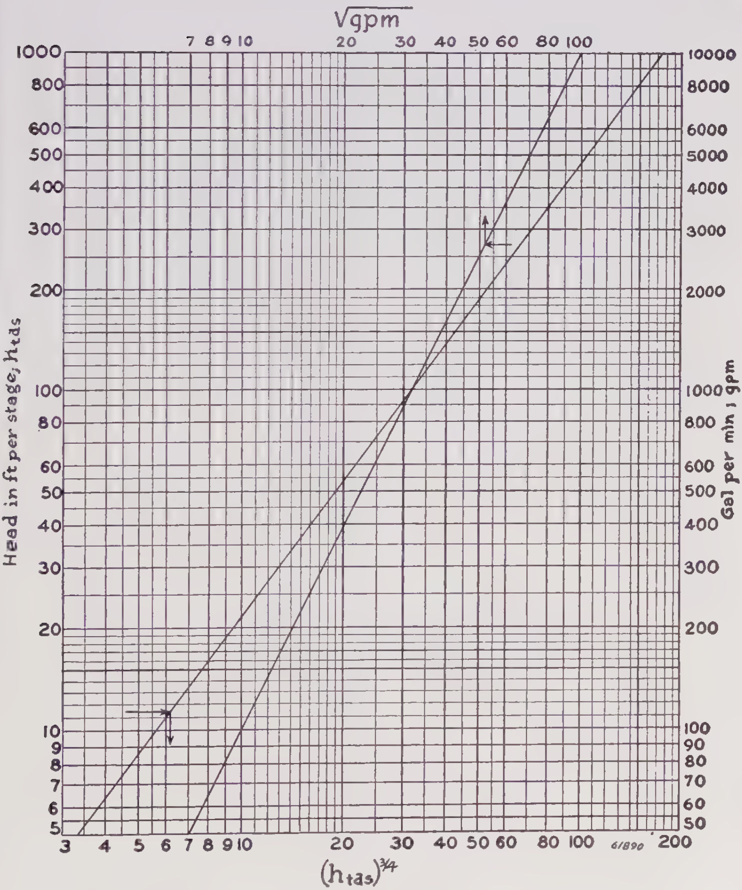
The Standards of the Hydraulic Institute contain very complete information on pipe friction. These may be obtained from the Institute at 122 E. 42 St., New York 17, N. Y. at a nominal cost.

Symbols used in this chapter:

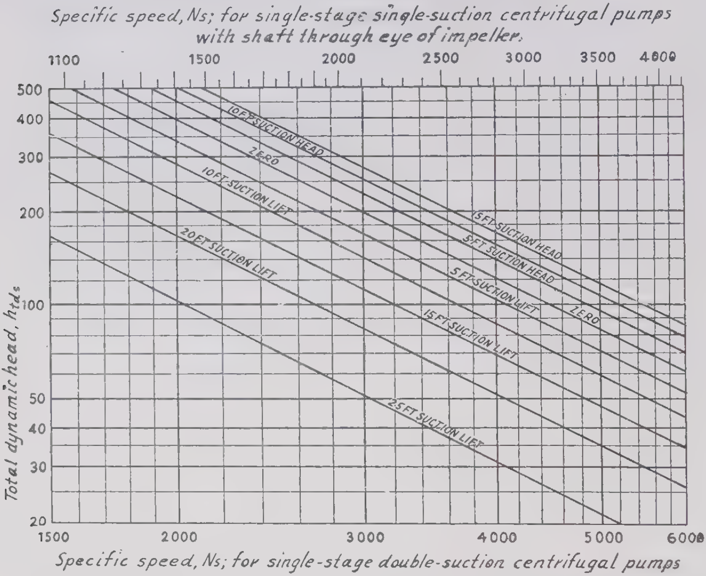
A = flow area of conduit in sq ft
Atm = atmospheric pressure in feet of liquid absolute
bph = flow in barrels (42 gal) per hr
d = inside diameter of circular conduit in inches
g = acceleration due to gravity in ft per sec^2 at sea level and 45° latitude this is 32.174 ft per sec per sec and this value has been used in conversions.
gpm = flow in gal per min
H = total head in ft of liquid
H_p = total head in lb per sq in
h_d = discharge head in ft of liquid
h_f = friction head in ft of liquid
h_s = suction head in ft of liquid
h_{sd} = static discharge head in ft
h_{ss} = static suction head in ft
h_{tds} = same as H (used in curves pgs 15 and 16)
h_{ts} = total static head in ft
h_v = velocity head in ft
l_s = suction lift in ft of liquid
l_{ss} = static suction lift in ft
Q = quantity of flow in cu ft per sec
s = specific gravity (water at 60F = 1)
v = velocity of flow in ft per sec
vp = vapor pressure of liquid in feet of liquid, absolute

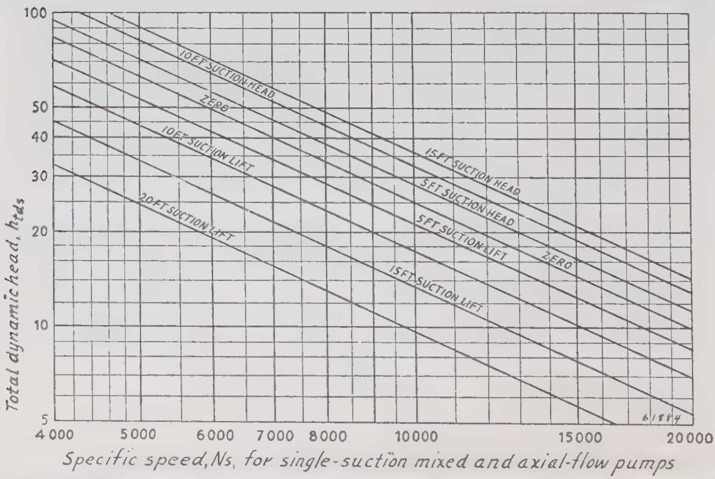
Values of $(h_{tds})^{3/4}$ and $\sqrt{gpm}$

(for computing Specific Speed)



Upper Limits of Specific Speeds
For clear water at sea level at 85F.

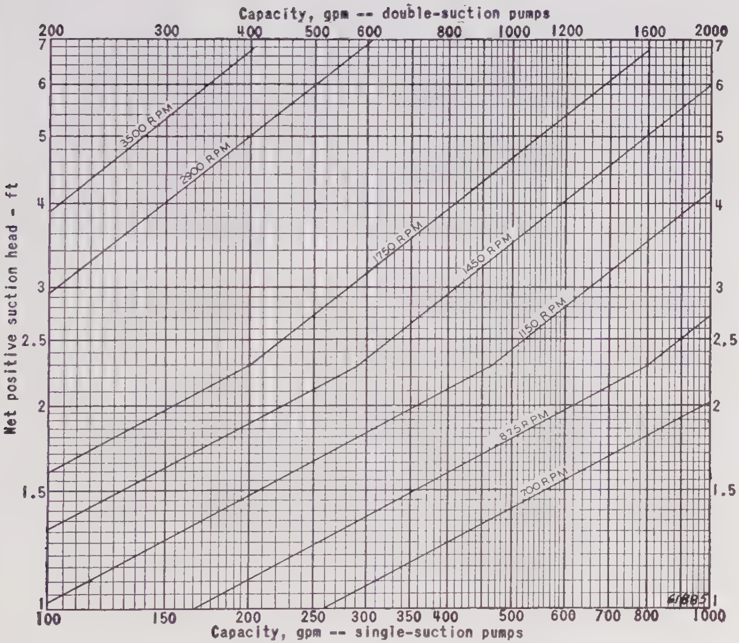




Reproduced by permission from standards of Hydraulic Institute. The lines on the chart are equivalent to the following net positive head over vapor pressure: 25 ft suct lift—7.6 ft; 20 ft suct lift—12.6 ft; 15 ft suct lift—17.6 ft; 10 ft suct lift—22.6 ft; 5 ft suct lift—27.6 ft; zero 32.6 ft; 5 ft suct head—37.6 ft; 10 ft suct head 42.6 ft; 15 ft suct head—47.6 ft.

1

Capacity and Speed Limitations For Condensate Pumps



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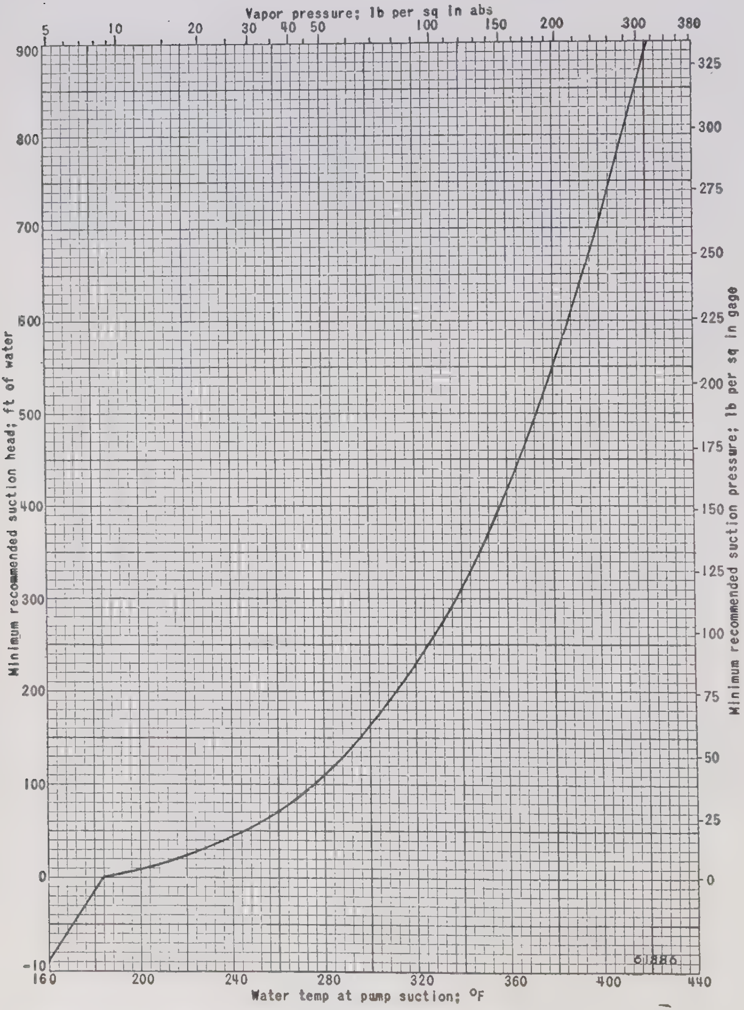
Suction Head Requirements
For pumping hot water



Based on a curve from the standards of the Hydraulic Institute.

CHAPTER II

WATER DATA

2

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WATER DATA

General Information on Water

Specific gravity of water is usually given as 1.0 at 60°F. However, for some purposes it is given as 1.0 at 39.2°F, the point of maximum density. Based on water at 39.2°F as 1.0, water at 60°F has a specific gravity of .999. Therefore which base is selected makes no practical difference.

Viscosity of water varies as follows:

	32F	50F	60F	70F	80F	100F	120F	140F	160F	180F	212F
absolute visc centipoises	1.79	1.31	1.12	.98	.86	.68	.56	.47	.40	.35	.28
Kinematic visc centistokes	1.79	1.31	1.12	.98	.86	.69	.57	.48	.41	.36	.29

Weight and Volume Equivalents

Convert from \ Convert to	U S gallon	Imperial gallon	Cubic inch	Cubic foot	* pound	* Cwt (U S)	* Ton (U S)	Liter	Cubic meter
U S gallon........	1.	.8327	231.	.13368	8.345	.08345	.00418	3.785	.00378
Imperial gal.....	1.201	1.	277.41	.1605	10.02	.1002	.00502	4 546	.00455
Cubic inch.......	.004329	.003607	1.	.000579	.036124	....	.....	.0164	.....
Cubic foot........	7.4805	6.232	1728.	1.	62.425	.6243	.03121	28.317	.0283
Pound*...........	.1198	.0998	27.68	.01602	1.	.01	.0005	.454	......
Cwt (U S)*.......	11.98	9.98	2768.	1.602	100.	1.	.05	45.36	.0454
Ton*(U S).......	239.6	199.6	....	32.04	2000.	20.0	1.	906.9	.907
Liter.............	.2642	.22	61.023	.0353	2.205	.022	.0011	1.	.001
Cubic meter......	264.2	220.	....	35.314	2204.5	22.045	1.102	1000.	1.

*Volume—weight relationships taken for water at greatest density (39.2. °F).

1 miner's inch of water = 8.977 gpm (in Idaho, Kansas, Nebraska, New Mexico, N. Dakota, S. Dakota, Utah, and Washington).
= 11.22 gpm (in Arizona, California, Montana, Nevada, and Oregon).
= 11.69 gpm (in Colorado)

1 second-foot (cu. ft per sec.) of water = 448.83 gpm

1 common water pail contains 19 pounds, or 2.27 U S gallons of water.

Barrels per day (42 gal) × .02917 = gal per min
(31 gal) × .02153 = gal per min
(45 gal) × .03125 = gal per min

Pressure, Lb per Sq In. to Feet (Head) of Water

$$ft = 2.31 \times lb/sq\ in.$$

Based on water at its greatest density (39.2°F)

Pressure Pounds Per Square Inch	Feet Head	Pressure Pounds Per Square Inch	Feet Head	Pressure Pounds Per Square Inch	Feet Head	Pressure Pounds Per Square Inch	Feet Head	Pressure Pounds Per Square Inch	Feet Head	Pressure Pounds Per Square Inch	Feet Head	Pressure Pounds Per Square Inch	Feet Head
1	2.31	53	122.43	105	242.55	157	362.67	209	482.79	261	602.91	365	843.15
2	4.62	54	124.74	106	244.86	158	364.98	210	485.10	262	605.22	370	854.70
3	6.93	55	127.05	107	247.17	159	367.29	211	487.41	263	607.53	375	866.25
4	9.23	56	129.36	108	249.48	160	369.60	212	489.72	264	609.84	380	877.80
5	11.55	57	131.67	109	251.79	161	371.91	213	492.03	265	612.15	385	899.35
6	13.86	58	133.98	110	254.10	162	374.22	214	494.34	266	614.46	390	900.90
7	16.17	59	136.29	111	256.41	163	375.53	215	496.65	267	616.77	395	912.45
8	18.48	60	138.60	112	258.72	164	378.84	216	498.96	268	619.08	400	924.00
9	20.79	61	140.91	113	261.03	165	381.15	217	501.27	269	621.39	405	931.55
10	23.10	62	143.22	114	263.34	166	383.46	218	503.58	270	623.70	410	947.10
11	25.41	63	145.53	115	265.65	167	385.77	219	505.89	271	626.01	415	958.65
12	27.72	64	147.84	116	267.96	168	388.08	220	508.20	272	628.32	420	970.20
13	30.03	65	150.15	117	270.27	169	390.39	221	510.51	273	630.63	425	981.75
14	32.34	66	152.46	118	272.58	170	392.70	222	512.82	274	632.94	430	993.30
15	34.65	67	154.77	119	274.89	171	395.01	223	515.13	275	635.25	435	1004.85
16	36.96	68	157.08	120	277.20	172	397.32	224	517.44	276	637.56	440	1016.40
17	39.27	69	159.39	121	279.51	173	399.63	225	519.75	277	639.87	445	1027.95
18	41.58	70	161.70	122	281.82	174	410.94	226	522.06	278	642.18	450	1039.50
19	43.89	71	164.01	123	284.13	175	404.25	227	524.37	279	644.49	455	1051.05
20	46.20	72	166.32	124	286.44	176	406.56	228	526.68	280	646.80	460	1062.60
21	48.51	73	168.63	125	288.75	177	408.87	229	528.99	281	649.11	465	1074.15
22	50.82	74	170.94	126	291.06	178	411.18	230	531.30	282	651.42	470	1085.70
23	53.13	75	173.25	127	293.37	179	413.49	231	533.61	283	653.73	475	1097.25
24	55.44	76	175.56	128	295.68	180	415.80	232	535.92	284	656.04	480	1108.80
25	57.75	77	177.87	129	297.99	181	418.11	233	538.23	285	658.35	485	1120.35
26	60.06	78	180.18	130	300.30	182	420.42	234	540.54	286	660.66	490	1131.90
27	62.37	79	182.49	131	302.61	183	422.73	235	542.85	287	662.97	495	1143.45
28	64.68	80	184.80	132	304.92	184	425.04	236	545.16	288	665.28	500	1155.00
29	66.99	81	187.11	133	307.23	185	427.35	237	547.47	289	667.59	525	1212.75
30	69.30	82	189.42	134	309.54	186	429.66	238	549.78	290	669.90	550	1270.50
31	71.71	83	191.73	135	311.85	187	431.97	239	552.09	291	672.21	575	1328.25
32	73.92	84	194.04	136	314.16	188	434.28	240	554.40	292	674.52	600	1386.00
33	76.23	85	196.35	137	316.47	189	436.59	241	556.71	293	676.83	625	1443.75
34	78.54	86	198.66	138	318.78	190	438.90	242	559.02	294	679.14	650	1501.50
35	80.85	87	200.97	139	321.09	191	441.21	243	561.33	295	681.45	675	1559.25
36	83.16	88	203.28	140	323.40	192	443.52	244	563.64	296	683.76	700	1617.00
37	85.47	89	205.59	141	325.71	193	445.83	245	565.95	297	686.07	725	1674.75
38	87.78	90	207.90	142	328.02	194	448.14	246	568.62	298	688.38	750	1732.50
39	90.09	91	210.21	143	330.33	195	450.45	247	570.57	299	690.69	775	1790.25
40	92.40	92	212.52	144	332.64	196	452.76	248	572.88	300	693.00	800	1848.00
41	94.71	93	214.83	145	334.95	197	445.07	249	575.19	305	704.55	825	1905.75
42	97.02	94	217.14	146	337.26	198	457.38	250	577.50	310	716.10	850	1963.50
43	99.33	95	219.45	147	339.57	199	459.69	251	579.81	315	727.65	875	2021.25
44	101.64	96	221.76	148	341.88	200	462.00	252	582.12	320	739.20	900	2079.00
45	103.95	97	224.07	149	344.19	201	464.31	253	584.43	325	750.75	925	2136.75
46	106.26	98	226.38	150	346.50	202	466.62	254	586.74	330	762.30	950	2194.50
47	108.57	99	228.69	151	348.81	203	468.93	255	589.05	335	773.85	975	2252.25
48	110.88	100	231.00	152	351.12	204	471.24	256	591.36	340	785.40	1000	2310.00
49	113.19	101	233.31	153	353.43	205	473.55	257	593.67	345	796.95	1500	3465.
50	115.50	102	235.62	154	355.74	206	475.86	258	595.98	350	808.50	2000	4620.
51	117.81	103	237.93	155	358.05	207	478.17	259	598.29	355	820.15	3000	6930.
52	120.12	104	240.24	156	360.36	208	480.48	260	600.60	360	831.60		

Pressure, Feet (head) of Water to Lb per Sq In.
lb/sq in. =.4331×ft

Based on water at its greatest density (39.2°F.)

Feet Head	Pressure Pounds per Square Inch	Feet Head	Pressure Pounds per Square Inch	Feet Head	Pressure Pounds per Square Inch	Feet Head	Pressure Pounds per Square Inch	Feet Head	Pressure Pounds per Square Inch	Feet Head	Pressure Pounds per Square Inch
1	0.43	54	23.39	107	46.34	160	69.31	213	92.20	285	123.45
2	0.86	55	23.82	108	46.78	161	69.74	214	92.69	290	125.62
3	1.30	56	24.26	109	47.21	162	70.17	215	93.13	295	127.78
4	1.73	57	24.69	110	47.64	163	70.61	216	93.56	300	129.95
5	2.16	58	25.12	111	48.08	164	71.04	217	93.99	305	132.12
6	2.59	59	25.55	112	48.51	165	71.47	218	94.43	310	134.28
7	3.03	60	25 99	113	48.94	166	71.91	219	94.86	315	136.46
8	3.46	61	26.42	114	49.38	167	72.34	220	95.30	320	138.62
9	3.89	62	26.85	115	49.81	168	72.77	221	95.73	325	140.79
10	4.33	63	27.29	116	50.24	169	73.20	222	96.16	330	142.95
11	4.76	64	27.72	117	50.68	170	73.64	223	96.60	335	145.12
12	5.20	65	28.15	118	51.11	171	74.07	224	97.03	340	147.28
13	5.63	66	28.58	119	51.54	172	74.50	225	97.46	345	149.45
14	6.06	67	29.02	120	51.98	173	74.94	226	97.90	350	151.61
15	6.49	68	29.45	121	52.41	174	75.37	227	98.33	355	153.78
16	6.93	69	29.88	122	52.84	175	75.80	228	98 76	360	155.94
17	7.36	70	30.32	123	53 28	176	76.23	229	99.20	365	158 10
18	7.79	71	30.75	124	53.71	177	76.67	230	99.63	370	160.27
19	8.22	72	31.18	125	54.15	178	77.10	231	100 0	375	162.45
20	8.66	73	31.62	126	54.58	179	77.53	232	100.49	380	164.61
21	9.09	74	32.05	127	55.01	180	77.97	233	100 93	385	166.78
22	9.53	75	32.48	128	55.44	181	78.40	234	101.36	390	168.94
23	9.96	76	32.92	129	55.88	182	78.84	235	101 70	395	171.11
24	10.39	77	33.35	130	56.31	183	79.27	236	102.23	400	173.27
25	10.82	78	33.78	131	56.74	184	79.70	237	102 66	425	184.10
26	11.26	79	34.21	132	57.18	185	80.14	238	103 09	450	195.0
27	11.69	80	34.65	133	57.61	186	80.57	239	103.53	475	205.77
28	12.12	81	35.08	134	58.04	187	81.0	240	103 96	500	216.58
29	12.55	82	35 52	135	58.48	188	81.43	241	104.39	525	227 42
30	12.99	83	35.95	136	58.91	189	81.87	242	104 83	550	238.25
31	13.42	84	36.39	137	59.34	190	82.30	243	105.26	575	249.09
32	13.86	85	36.82	138	59.77	191	82.73	244	105.69	600	259.90
33	14.29	86	37.25	139	60.21	192	83.17	245	106.13	625	270.73
34	14.72	87	37.68	140	60.64	193	83.60	246	106 56	650	281.56
35	15.16	88	38.12	141	61.07	194	84.03	247	106 99	675	292.40
36	15.59	89	38.55	142	61.51	195	84.47	248	107.43	700	303.22
37	16.02	90	38.98	143	61.94	196	84.90	249	107.86	725	314.05
38	16.45	91	39.42	144	62.37	197	85.33	250	108.29	750	324.88
39	16.89	92	39.85	145	62.81	198	85.76	251	108.73	775	335.72
40	17.32	93	40.28	146	63.24	199	86.20	252	109.16	800	346.54
41	17.75	94	40.72	147	63.67	200	86.63	253	109.59	825	357.37
42	18.19	95	41.15	148	64.10	201	87.07	254	110.03	850	368.20
43	18.62	96	41.58	149	64.54	202	87.50	255	110.46	875	379 03
44	19.05	97	42.01	150	64 97	203	87.93	256	110 89	900	389.86
45	19.49	98	42.45	151	65.40	204	88.36	257	111.32	925	400.70
46	19.92	99	42.88	152	65.84	205	88.80	258	111.76	950	411.54
47	20.35	100	43.31	153	66.27	206	89.21	259	112.19	975	422.35
48	20.79	101	43.75	154	66.70	207	89.66	260	112.62	1000	433.18
49	21.22	102	44.18	155	67.14	208	90.10	261	113.06	1500	649.7
50	21.65	103	44.61	156	67.57	209	90.53	262	113.49	2000	866.3
51	22.09	104	45.05	157	68.0	210	90.96	270	116.96	3000	1,299.5
52	22.52	105	45.48	158	68.43	211	91.39	275	119.12		
53	22.95	106	45.91	159	68.87	212	91.83	280	121.29		

Table for Converting Inches of Mercury (at 32F) to Feet of Water (at 39.2F)

ft = 1.133 × in hg

Inches of Mercury in Tenths

Inches of Mercury	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1	1.133	1.246	1.359	1.473	1.586	1.699	1.813	1.925	2.039	2.153
2	2.266	2.38	2.492	2.605	2.72	2.833	2.946	3.06	3.172	3.286
3	3.399	3.512	3.625	3.74	3.85	3.965	4.08	4.19	4.3	4.42
4	4.532	4.645	4.76	4.87	4.985	5.1	5.21	5.325	5.44	5.55
5	5.665	5.78	5.89	6.00	6.12	6.23	6.344	6.46	6.57	6.684
6	6.798	6.91	7.024	7.138	7.25	7.364	7.48	7.6	7.7	7.817
7	7.931	8.044	8.157	8.27	8.384	8.4975	8.61	8.72	8.84	8.95
8	9.064	9.177	9.29	9.40	9.517	9.63	9.74	9.857	9.97	10.088
9	10.197	10.31	10.42	10.536	10.65	10.76	10.87	10.99	11.10	11.216
10	11.33	11.443	11.556	11.67	11.78	11.896	12.01	12.123	12.236	12.35
11	12.46	12.576	12.69	12.80	12.91	13.03	13.142	13.256	13.37	13.483
12	13.596	13.71	13.82	13.935	14.05	14.162	14.275	14.39	14.50	14.615
13	14.73	14.84	14.95	15.07	15.18	15.295	15.408	15.522	15.635	15.748
14	15.86	15.975	16.088	16.20	16.315	16.428	16.54	16.655	16.77	16.88
15	16.99	17.108	17.22	17.335	17.49	17.561	17.674	17.788	17.9	18.014
16	18.13	18.24	18.354	18.467	18.58	18.694	18.807	18.92	19.034	19.147
17	19.26	19.37	19.487	19.6	19.714	19.827	19.94	20.05	20.167	20.28
18	20.39	20.51	20.62	20.73	20.847	20.96	21.07	21.187	21.30	21.41
19	21.53	21.64	21.753	21.866	21.98	22.09	22.2	22.317	22.43	22.543
20	22.66	22.77	22.883	22.996	23.11	23.223	23.336	23.45	23.563	23.676
21	23.79	23.90	24.01	24.129	24.243	24.356	24.47	24.583	24.696	24.81
22	24.926	25.04	25.152	25.265	25.38	25.5	25.6	25.72	25.83	25.945
23	26.06	26.17	26.28	26.398	26.51	26.62	26.74	26.85	26.965	27.078
24	27.2	27.305	27.418	27.53	27.645	27.76	27.87	27.985	28.098	28.21
25	28.325	28.438	28.55	28.66	28.78	28.89	29.	29.118	29.23	29.344
26	29.46	29.572	29.685	29.798	29.91	30.025	30.138	30.25	30.365	30.478
27	30.6	30.705	30.82	30.93	31.04	31.16	31.27	31.385	31.498	31.61
28	31.7	31.84	31.95	32.06	32.18	32.29	32.4	32.52	32.63	32.744
29	32.86	32.96	33.07	33.18	33.3	33.413	33.526	33.64	33.753	33.866
30	33.99									

SP GR = $\frac{\text{[illegible]}}{62.37}$

Properties of water at saturation pressure

Temp °F	Pressure lb/in² abs	Specific volume		Density		Conversion factor ft/lb/in²	Temp °F
		ft³/lb	gal/lb	lb/ft³	gr/cm³		
32	.0885	.01602	.1198	62.42	.9999	2.307	32
33	.0922	.01602	.1198	62.42	.9999	2.307	33
34	.0960	.01602	.1198	62.42	.9999	2.307	34
35	.1000	.01602	.1198	62.424	1.0000	2.307	35
36	.1040	.01602	.1198	62.425	1.0000	2.307	36
37	.1082	.01602	.1198	62.426	1.0000	2.307	37
38	.1126	.01602	.1198	62.426	1.0000	2.307	38
39	.1171	.01602	.1198	62.426	1.0000	2.307	39
40	.1217	.01602	.1198	62.426	1.0000	2.307	40
41	.1265	.01602	.1198	62.426	1.0000	2.307	41
42	.1315	.01602	.1198	62.425	1.0000	2.307	42
43	.1367	.01602	.1198	62.424	1.0000	2.307	43
44	.1420	.01602	.1198	62.42	.9999	2.307	44
45	.1475	.01602	.1198	62.42	.9999	2.307	45
46	.1532	.01602	.1198	62.42	.9999	2.307	46
47	.1591	.01603	.1199	62.42	.9999	2.307	47
48	.1653	.01603	.1199	62.41	.9998	2.307	48
49	.1716	.01603	.1199	62.41	.9998	2.307	49
50	.1781	.01603	.1199	62.41	.9997	2.307	50
51	.1849	.01603	.1199	62.41	.9997	2.307	51
52	.1918	.01603	.1199	62.40	.9996	2.308	52
53	.1990	.01603	.1199	62.40	.9996	2.308	53
54	.2064	.01603	.1199	62.40	.9995	2.308	54
55	.2141	.01603	.1199	62.39	.9994	2.308	55
56	.2220	.01603	.1199	62.39	.9994	2.308	56
57	.2302	.01603	.1199	62.38	.9993	2.308	57
58	.2386	.01604	.1200	62.38	.9992	2.308	58
59	.2473	.01604	.1200	62.37	.9991	2.309	59
60	.2563	.01604	.1200	62.37	.9990	2.309	60
62	.2751	.01604	.1200	62.36	.9989	2.309	62
64	.2951	.01605	.1201	62.35	.9987	2.310	64
66	.3164	.01605	.1201	62.33	.9985	2.310	66
68	.3390	.01605	.1201	62.32	.9982	2.311	68
70	.3631	.01606	.1201	62.30	.9980	2.311	70
75	.4298	.01607	.1202	62.27	.9974	2.313	75
80	.5069	.01608	.1203	62.22	.9966	2.315	80
85	.5959	.01609	.1204	62.17	.9959	2.316	85
90	.6982	.01610	.1205	62.12	.9950	2.318	90
95	.8153	.01612	.1206	62.06	.9941	2.320	95
100	.9492	.01613	.1207	62.00	.9931	2.323	100
110	1.275	.01617	.1210	61.84	.9906	2.328	110
120	1.692	.01620	.1212	61.73	.9888	2.333	120
130	2.223	.01625	.1215	61.54	.9857	2.340	130
140	2.889	.01629	.1219	61.39	.9833	2.346	140
150	3.718	.01634	.1222	61.20	.9803	2.353	150
160	4.741	.01639	.1226	61.01	.9773	2.360	160
170	5.992	.01645	.1230	60.79	.9738	2.369	170
180	7.510	.01651	.1235	60.57	.9702	2.377	180
190	9.339	.01657	.1240	60.35	.9667	2.386	190

Properties of water at saturation pressure

Temp °F	Pressure lb/in² abs	Specific volume		Density		Conversion factor ft/lb/in²	Temp F
		ft³/lb	gal/lb	lb/ft³	gr/cm³		
200	11.53	.01663	.1244	60.13	.9632	2.395	200
210	14.12	.01670	.1249	59.88	.9592	2.405	210
220	17.19	.01677	.1254	59.63	.9552	2.415	220
230	20.78	.01684	.1260	59.38	.9512	2.425	230
240	24.97	.01692	.1266	59.10	.9467	2.436	240
250	29.83	.01700	.1272	58.82	.9423	2.448	250
260	35.43	.01709	.1278	58.51	.9373	2.461	260
270	41.85	.01717	.1284	58.24	.9331	2.472	270
280	49.20	.01726	.1291	57.94	.9281	2.485	280
290	57.56	.01735	.1298	57.64	.9232	2.498	290
300	67.01	.01745	.1305	57.31	.9180	2.513	300
310	77.68	.01755	.1313	56.98	.9127	2.527	310
320	89.66	.01765	.1320	56.66	.9076	2.542	320
330	103.1	.01776	.1329	56.31	.9019	2.557	330
340	118.0	.01787	.1337	55.96	.8964	2.573	340
350	135	.01799	.1346	55.59	.8904	2.591	350
360	153	.01811	.1355	55.22	.8845	2.608	360
370	173	.01823	.1364	54.85	.8787	2.625	370
380	196	.01836	.1373	54.47	.8725	2.644	380
390	220	.01850	.1384	54.05	.8659	2.664	390
400	247	.01864	.1394	53.65	.8594	2.684	400
410	277	.01878	.1405	53.25	.8529	2.704	410
420	309	.01894	.1417	52.80	.8457	2.727	420
430	344	.01910	.1429	52.36	.8387	2.750	430
440	382	.01926	.1441	51.92	.8317	2.773	440
450	423	.0194	.145	51.5	.826	2.79	450
460	467	.0196	.147	51.0	.817	2.82	460
470	515	.0198	.148	50.5	.809	2.85	470
480	566	.0200	.150	50.0	.801	2.88	480
490	621	.0202	.151	49.5	.793	2.91	490
500	681	.0204	.153	49.0	.785	2.94	500
510	744	.0207	.155	48.3	.774	2.98	510
520	812	.0209	.156	47.8	.766	3.01	520
530	885	.0212	.159	47.2	.756	3.05	530
540	963	.0215	.161	46.5	.745	3.10	540
550	1045	.0218	.163	45.9	.735	3.14	550
560	1133	.0221	.165	45.2	.725	3.18	560
570	1227	.0224	.168	44.6	.715	3.23	570
580	1326	.0228	.171	43.9	.703	3.28	580
590	1431	.0232	.174	43.1	.690	3.34	590
600	1543	.0236	.177	42.4	.679	3.40	600
610	1661	.0241	.180	41.5	.665	3.47	610
620	1787	.0247	.185	40.5	.649	3.56	620
630	1919	.0253	.189	39.5	.633	3.64	630
640	2060	.0260	.194	38.5	.616	3.74	640
650	2208	.0268	.200	37.3	.598	3.86	650
670	2532	.0290	.217	34.5	.552	4.18	670
690	2895	.0328	.245	30.5	.488	4.71	690
705.4	3206	.0503	.376	19.9	.318	7.24	705

Calculated from data in Keenan and Keyes Steam Tables (1936) except densities from 32 to 100F which are taken from US Bureau of Standards circular no 19.

Friction losses in pipes carrying water

Among the many empirical formulae for friction losses that have been proposed, that of Williams and Hazen has been most widely used. In a convenient form it reads:

$$f = 0.2083\left(\frac{100}{C}\right)^{1.85}\frac{q^{1.85}}{d^{4.8655}}$$

in which

f = friction head in ft of liquid per 100 ft of pipe (if desired in lb per sq in. multiply f × .433 × sp gr)

d = inside dia of pipe in inches

q = flow in gal per min

C = constant accounting for surface roughness

2

This formula gives accurate values only when the kinematic viscosity of the liquid is about 1.1 centistokes or 31.5 SSU, which is the case with water at about 60F. But the viscosity of water varies with the temperature from 1.8 at 32F to .29 centistokes at 212F. The tables are therefore subject to this error, which may increase the friction loss as much as 20% at 32F and decrease it as much as 20% at 212F. Note that the tables may be used for any liquid having a viscosity of the same order as indicated above.

Values of C for various types of pipe are given below together with the corresponding multiplier which should apply to the tabulated values of the head loss, f, as given on pages 130 to 144.

TYPE OF PIPE	VALUES OF C		
	Range — High = best, smooth, well laid — Low = poor or corroded	Average value for good, clean, new pipe	Commonly used value for design purposes
Cement—Asbestos	160–140	150	140
Fibre	—	150	140
Bitumastic-enamel-lined iron or steel centrifugally applied	160–130	148	140
Cement-lined iron or steel centrifugally applied	—	150	140
Copper, brass, lead, tin or glass pipe and tubing	150–120	140	130
Wood-stave	145–110	120	110
Welded and seamless steel	150–80	140	100
Continuous-interior riveted steel (no projecting rivets or joints	—	139	100
Wrought-iron	150–80	130	100
Cast-iron	150–80	130	100
Tar-coated cast-iron	145–80	130	100
Girth-riveted steel (projecting rivets in girth seams only)	—	130	100
Concrete	152–85	120	100
Full-riveted steel (projecting rivets in girth and horizontal seams)	—	115	100
Vitrified	—	110	100
Spiral-riveted steel (flow with lap)	—	110	100
Spiral-riveted steel (flow against lap)	—	100	90
Corrugated steel	—	60	60

Value of C	150	140	130	120	110	100	90	80	70	60
Multiplier to correct tables	.47	.54	.62	.71	.84	1.0	1.22	1.50	1.93	2.57

Friction Losses In Pipe; C=100 (For old pipe)

1/8 Inch

FLOW US gal per min	STANDARD WT STEEL .269″ inside dia			EXTRA STRONG STEEL .215″ inside dia		
	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
0.1	.565	.00	1.75	.884	.01	5.21
0.2	1.13	.02	6.31	1.77	.05	18.8
0.3	1.69	.04	13.4	2.65	.11	39.8
0.4	2.26	.08	22.8	3.54	.19	67.7
0.5	2.83	.12	34.4	4.42	.30	102
0.6	3.39	.18	48.2	5.32	.44	147
0.7	3.95	.24	64.1	6.29	.61	191
0.8	4.52	.32	82.0	7.08	.78	244
0.9	5.08	.40	102	7.96	.98	303
1.0	5.65	.50	124	8.84	1.21	369

1/4 Inch

FLOW US gal per min	STANDARD WT STEEL .364″ inside dia			EXTRA STRONG STEEL .302″ inside dia		
	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
0.4	1.23	.02	5.22	1.79	.05	13.0
0.6	1.85	.05	11.1	2.69	.11	27.4
0.8	2.47	.09	18.8	3.59	.20	46.7
1.0	3.08	.15	28.5	4.48	.31	70.6
1.2	3.71	.21	39.9	5.38	.45	98.9
1.4	4.33	.29	53.0	6.27	.61	132
1.6	4.94	.38	67.9	7.17	.80	168
1.8	5.55	.48	84.4	8.07	1.01	209
2.0	6.17	.59	103	8.96	1.25	254
2.5	7.71	.92	155	11.2	1.95	385

3/8 Inch

FLOW US gal per min	STANDARD WT STEEL .493″ inside dia			EXTRA STRONG STEEL .423″ inside dia		
	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
0.8	1.35	.03	4.30	1.83	.05	9.07
1.0	1.68	.04	6.50	2.28	.08	13.7
1.5	2.52	.10	13.8	3.43	.18	29.0
2.0	3.36	.18	23.4	4.57	.32	49.4
2.5	4.21	.28	35.4	5.71	.51	74.6
3.0	5.05	.40	49.6	6.85	.73	105
3.5	5.89	.54	66.0	8.00	.99	139
4.0	6.73	.70	84.5	9.14	1.30	178
5.0	8.41	1.10	134	11.4	2.0	269
6.0	10.1	1.58	179	13.7	2.9	377

Friction Losses in Pipe; C = 100 (For Old Pipe*)

½ Inch

FLOW US gal per min	Standard Wt Steel .622″ inside dia Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Extra Strong Steel .546″ inside dia Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Double Extra Strong Steel .252″ inside dia Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
0.5	.528	.00	.582	.686	.01	1.10	3.22	.16	47.2
1.0	1.06	.02	2.10	1.37	.03	3.96	6.44	.64	170
1.5	1.58	.04	4.44	2.06	.07	8.38	9.66	1.45	361
2.0	2.11	.07	7.57	2.74	.12	14.3	12.9	2.59	614
2.5	2.64	.11	11.4	3.43	.18	21.6	16.1	4.03	928
3.0	3.17	.16	16.0	4.11	.26	30.2			
3.5	3.70	.21	21.3	4.80	.36	40.2			
4.0	4.23	.28	27.3	5.48	.47	51.4			
4.5	4.75	.35	33.9	6.17	.59	64.0			
5.0	5.28	.43	41.2	6.86	.73	77.7			
5.5	5.81	.52	49.2	7.54	.88	92.7			
6.0	6.34	.62	57.8	8.23	1.05	109			
6.5	6.87	.73	67.0	8.91	1.23	126			
7.0	7.39	.85	76.8	9.60	1.43	145			
7.5	7.92	.97	87.3	10.3	1.6	165			
8.0	8.45	1.11	98.3	11.0	1.9	185			
8.5	8.98	1.25	110	11.6	2.1	207			
9.0	9.51	1.4	122	12.3	2.4	231			
9.5	10.0	1.6	135	13.0	2.6	255			
10	10.6	1.7	149	13.7	2.9	280			

¾ Inch

FLOW US gal per min	Standard Wt Steel .824″ inside dia Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Extra Strong Steel .742″ inside dia Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Double Extra Strong Steel .434″ inside dia Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
1.5	.903	.01	1.13	1.11	.02	1.88	3.25	.16	25.6
2.0	1.20	.02	1.93	1.48	.03	3.21	4.34	.29	43.6
2.5	1.51	.04	2.91	1.86	.05	4.85	5.42	.46	65.9
3.0	1.81	.05	4.08	2.23	.08	6.79	6.51	.66	92.3
3.5	2.11	.07	5.42	2.60	.11	9.03	7.60	.90	123
4.0	2.41	.09	6.94	2.97	.14	11.6	8.68	1.17	157
4.5	2.71	.11	8.63	3.34	.17	14.4	9.77	1.48	195
5	3.01	.14	10.5	3.71	.21	17.5	10.9	1.8	238
6	3.61	.20	14.7	4.45	.31	24.5	13.0	2.6	333
7	4.21	.28	19.6	5.20	.42	32.6	15.2	3.6	443
8	4.82	.36	25.0	5.94	.55	41.7	17.4	4.7	567
9	5.42	.46	31.1	6.68	.69	51.8	19.5	5.9	704
10	6.02	.56	37.8	7.42	.86	63.0	21.7	7.3	856
11	6.62	.68	45.1	8.17	1.04	75.1			
12	7.22	.81	53.0	8.91	1.23	88.3			
13	7.82	.95	61.5	9.63	1.44	102			
14	8.43	1.10	70.5	10.4	1.7	117			
16	9.63	1.44	90.2	11.9	2.2	150			
18	10.8	1.8	112	13.4	2.8	187			
20	12.0	2.2	136	14.8	3.4	227			

*For new pipe—multiply head loss figures by 0.54.

Friction Losses In Pipe; C=100 (For Old Pipe)

1 Inch

FLOW	Standard Wt Steel 1.049″ inside dia			Extra Strong Steel .957″ inside dia			Double Extra Strong Steel .599″ inside dia		
U S gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
2	.742	.01	.595	.892	.01	.930	2.28	.08	11.7
3	1.11	.02	1.26	1.34	.03	1.97	3.42	.18	24.8
4	1.49	.03	2.14	1.79	.05	3.28	4.56	.32	42.2
5	1.86	.05	3.24	2.23	.08	5.07	5.69	.50	63.8
6	2.23	.08	4.54	2.68	.11	7.10	6.83	.72	69.4
8	2.97	.14	7.73	3.57	.20	12.1	9.11	1.29	152
10	3.71	.21	11.7	4.46	.31	18.3	11.4	2.0	230
12	4.46	.31	16.4	5.36	.45	25.6	13.7	2.9	322
14	5.20	.42	21.8	6.25	.61	34.0	15.9	3.9	429
16	5.94	.55	27.9	7.14	.79	43.6	18.2	5.1	549
18	6.68	.69	34.7	8.03	1.00	54.2	20.5	6.5	682
20	7.43	.86	42.1	8.92	1.24	65.8	22.7	8.0	829
22	8.17	1.04	50.2	9.82	1.50	78.5	25.1	9.8	989
24	8.91	1.23	59.0	10.7	1.8	94.4			
26	9.66	1.45	68.4	11.6	2.1	107			
28	10.4	1.7	78.5	12.5	2.4	123			
30	11.1	1.9	89.2	13.4	2.8	139			
35	13.0	2.6	119	15.6	3.8	185			
40	14.9	3.5	152	17.9	5.0	237			
45	16.7	4.3	189	20.1	6.3	295			

1¼ Inch

FLOW	Standard Wt Steel 1.380″ inside dia			Extra Strong Steel 1.278″ inside dia			Double Extra Strong Steel .896″ inside dia		
U S gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
4	.86	.01	.564	1.00	.02	.821	2.04	.06	4.63
5	1.07	.02	.853	1.25	.02	1.24	2.54	.10	6.98
6	1.29	.03	1.20	1.50	.04	1.74	3.05	.14	9.78
7	1.50	.04	1.59	1.75	.05	2.31	3.56	.20	13.0
8	1.72	.05	2.04	2.00	.06	2.96	4.07	.26	16.7
10	2.15	.07	3.08	2.50	.10	4.47	5.09	.40	25.2
12	2.57	.10	4.31	3.00	.14	6.26	6.11	.58	35.3
14	3.00	.14	5.73	3.50	.19	8.33	7.12	.79	46.9
16	3.43	.18	7.34	4.00	.25	10.7	8.14	1.03	60.0
18	3.86	.23	9.13	4.50	.31	13.3	9.16	1.30	74.7
20	4.29	.29	11.1	5.00	.39	16.1	10.2	1.6	90.7
25	5.36	.45	16.8	6.25	.61	24.9	12.7	2.5	137
30	6.43	.64	23.5	7.50	.87	34.1	15.3	3.6	192
35	7.51	.88	31.2	8.75	1.19	45.4	17.8	4.9	256
40	8.58	1.14	40.0	10.0	1.6	58.1	20.4	6.5	327
50	10.7	1.8	60.4	12.5	2.4	87.8	25.4	10.0	494
60	12.9	2.6	84.7	15.0	3.5	123	30.5	14.5	692
70	15.0	3.5	114	17.5	4.8	164	35.6	19.7	921
80	17.2	4.6	144	20.0	6.2	209			
90	19.3	5.8	179	22.5	7.9	260			

Friction Losses In Pipe; C=100 (For Old Pipe)
1½ Inch

FLOW	Standard Wt Steel			Extra Strong Steel			Double Extra Strong Steel		
	1.610″ inside dia			1.500″ inside dia			1.100″ inside dia		
U S gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
4	.63	.01	.267	.73	.01	.376	1.35	.03	1.70
5	.79	.01	.403	.91	.01	.569	1.69	.04	2.57
6	.95	.01	.565	1.09	.02	.797	2.03	.06	3.60
7	1.10	.02	.751	1.27	.03	1.06	2.36	.09	4.79
8	1.26	.02	.962	1.45	.03	1.36	2.70	.11	6.14
9	1.42	.03	1.20	1.63	.04	1.69	3.04	.14	7.63
10	1.58	.04	1.45	1.82	.05	2.05	3.38	.18	9.27
12	1.89	.06	2.04	2.18	.07	2.87	4.05	.25	13.0
14	2.21	.08	2.71	2.54	.10	3.82	4.73	.35	17.3
16	2.52	.10	3.47	2.90	.13	4.89	5.40	.45	22.1
18	2.84	.13	4.31	3.27	.17	6.08	6.08	.57	27.5
20	3.15	.15	5.24	3.63	.20	7.39	6.75	.71	33.4
22	3.47	.19	6.25	3.99	.25	8.82	7.43	.86	39.9
24	3.78	.22	7.34	4.36	.30	10.4	8.10	1.02	46.8
26	4.10	.26	8.51	4.72	.35	12.0	8.78	1.20	54.3
28	4.41	.30	9.76	5.08	.40	13.8	9.45	1.39	62.3
30	4.73	.35	11.1	5.45	.46	15.7	10.1	1.6	70.8
32	5.04	.39	12.5	5.81	.52	17.6	10.8	1.8	79.8
34	5.36	.45	14.0	6.17	.59	19.7	11.5	2.1	89.2
36	5.67	.50	15.5	6.54	.66	21.9	12.2	2.3	99.2
38	5.99	.56	17.2	6.90	.74	24.2	12.8	2.5	110
40	6.30	.62	18.9	7.26	.82	26.7	13.5	2.8	121
42	6.62	.68	20.7	7.63	.90	29.2	14.2	3.1	132
44	6.93	.75	22.5	7.99	.99	31.8	14.9	3.5	144
46	7.25	.82	24.5	8.35	1.08	34.5	15.6	3.8	156
48	7.57	.89	27.1	8.72	1.18	37.3	16.2	4.1	169
50	7.88	.97	28.5	9.08	1.28	40.3	16.9	4.4	182
55	8.67	1.17	34.0	9.99	1.55	49.0	18.6	5.4	217
60	9.46	1.39	40.0	10.9	1.8	56.4	20.3	6.4	255
65	10.2	1.6	46.4	11.8	2.2	65.4	21.9	7.5	296
70	11.0	1.9	53.2	12.7	2.5	75.0	23.6	8.7	339
75	11.8	2.2	60.4	13.6	2.9	85.3	25.3	9.9	386
80	12.6	2 5	68.1	14.5	3.3	96.1	27.0	11.3	435
85	13.4	2.8	76.2	15.4	3.7	107	28.7	12.8	486
90	14.2	3.1	84.7	16.3	4.1	119	30.4	14.4	540
95	15.0	3.5	93.6	17.2	4.6	132	32.1	16.0	597
100	15.8	3.9	103	18.2	5.1	145	33.8	17.8	657
110	17.3	4.7	123	20.0	6.2	173			
120	18.9	5.6	144	21.8	7.4	203			
130	20.5	6.5	167	23.6	8.7	236			
140	22.1	7.6	192	25.4	10.0	271			
150	23.6	8.7	218	27.2	11.5	308			
160	25.2	9.9	245	29.0	13.1	346			
170	26.8	11.2	275	30.9	14.8	387			
180	28.4	12.5	305	32.7	16.6	431			

Friction Losses In Pipe; C=100 (For Old Pipe)
2 Inch

FLOW	Standard Wt Steel			Extra Strong Steel			Double Extra Strong Steel		
	2.067″ inside dia			1.939″ inside dia			1.503″ inside dia		
U S gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
5	.48	.00	.120	.54	.00	.163	.90	.01	.563
6	.57	.01	.167	.65	.01	.229	1.09	.02	.789
7	.67	.01	.223	.76	.01	.304	1.27	.03	1.05
8	.77	.01	.285	.87	.01	.389	1.45	.03	1.34
9	.86	.01	.355	.98	.01	.484	1.63	.04	1.67
10	.96	.01	.431	1.09	.02	.588	1.81	.05	2.03
12	1.15	.02	.604	1.30	.03	.824	2.17	.07	2.85
14	1.34	.03	.803	1.52	.04	1.10	2.53	.10	3.78
16	1.53	.04	1.03	1.74	.05	1.40	2.89	.13	4.85
18	1.72	.05	1.28	1.96	.06	1.74	3.25	.16	6.02
20	1.91	.06	1.55	2.17	.07	2.12	3.62	.20	7.32
22	2.10	.07	1.85	2.39	.09	2.53	3.98	.25	8.73
24	2.29	.08	2.18	2.61	.11	2.97	4.34	.29	10.3
26	2.49	.10	2.52	2.83	.12	3.44	4.70	.34	11.9
28	2.68	.11	2.89	3.04	.14	3.95	5.06	.40	13.6
30	2.87	.13	3.29	3.26	.17	4.49	5.43	.46	15.5
35	3.35	.17	4.37	3.80	.22	5.97	6.33	.62	20.6
40	3.82	.23	5.60	4.35	.29	7.64	7.23	.81	26.4
45	4.30	.29	6.96	4.89	.37	9.50	8.14	1.03	32.8
50	4.78	.36	8.46	5.43	.46	11.5	9.04	1.27	39.9
55	5.26	.43	10.1	5.98	.56	13.7	9.95	1.54	47.5
60	5.74	.51	11.9	6.52	.66	16.2	10.9	1.8	54.6
65	6.21	.60	13.7	7.06	.77	18.8	11.8	2.2	64.8
70	6.69	.70	15.8	7.61	.90	21.5	12.7	2.5	74.3
75	7.17	.80	17.9	8.15	1.03	24.5	13.6	2.9	84.4
80	7.65	.91	20.2	8.69	1.17	27.6	14.5	3.3	95.2
85	8.13	1.03	22.6	9.03	1.27	30.8	15.4	3.7	106
90	8.61	1.15	25.1	9.78	1.49	34.3	16.3	4.1	118
95	9.08	1.28	27.7	10.3	1.6	37.9	17.2	4.6	131
100	9.56	1.42	30.5	10.9	1.8	41.6	18.1	5.1	144
110	10.5	1.7	36.4	12.0	2.2	49.7	19.9	6.2	172
120	11.5	2.1	42.7	13.0	2.6	58.3	21.7	7.3	201
130	12.4	2.4	49.6	14.1	3.1	67.7	23.5	8.6	234
140	13.4	2.8	56.9	15.2	3.6	77.6	25.3	9.9	268
150	14.3	3.2	64.7	16.3	4.1	88.4	27.1	11.4	305
160	15.3	3.6	72.8	17.4	4.7	99.3	28.9	13.0	343
170	16.3	4.1	81.4	18.5	5.3	111	30.7	14.6	384
180	17.2	4.6	90.5	19.6	6.0	124	32.5	16.4	427
190	18.2	5.1	100	20.6	6.6	137	34.4	18.4	471
200	19.1	5.7	110	21.7	7.3	150	36.2	20.4	518
220	21.0	6.8	131	23.9	8.9	179	39.8	24.6	618
240	22.9	8.2	154	26.1	10.6	210	43.4	29.3	726
260	24.9	9.6	179	28.3	12.4	244	47.0	34.3	842
280	26.8	11.2	205	30.4	14.4	280			
300	28.7	12.8	233	32.6	16.5	318			

Friction Losses In Pipe; C = 100 (For Old Pipe)
2½ Inch

FLOW	Standard Wt Steel			Extra Strong Steel			Double Extra Strong Steel		
	2.469″ inside dia			2.323″ inside dia			1.771″ inside dia		
U S gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
8	.54	.00	.120	.61	.01	.163	1.04	.02	.605
10	.67	.01	.182	.76	.01	.244	1.30	.03	.914
12	.80	.01	.254	.91	.01	.342	1.56	.04	1.28
14	.94	.01	.338	1.06	.02	.455	1.82	.05	1.70
16	1.07	.02	.433	1.21	.02	.583	2.08	.07	2.18
18	1.21	.02	.538	1.36	.03	.724	2.34	.09	2.71
20	1.34	.03	.654	1.51	.04	.880	2.73	.12	3.30
22	1.47	.03	.780	1.67	.04	1.050	2.87	.13	3.93
24	1.61	.04	.917	1.82	.05	1.23	3.13	.15	4.62
26	1.74	.05	1.06	1.97	.06	1.43	3.39	.18	5.35
28	1.88	.05	1.22	2.12	.07	1.64	3.65	.21	6.14
30	2.01	.06	1.39	2.27	.08	1.86	4.00	.25	6.98
35	2.35	.09	1.84	2.65	.11	2.48	4.56	.32	9.28
40	2.68	.11	2.36	3.03	.14	3.17	5.21	.42	11.9
45	3.02	.14	2.93	3.41	.18	3.95	5.86	.53	14.8
50	3.35	.17	3.56	3.79	.22	4.79	6.51	.66	18.0
55	3.69	.21	4.24	4.16	.27	5.71	7.16	.80	21.4
60	4.02	.25	4.99	4.54	.32	6.72	7.81	.95	25.2
65	4.36	.30	5.79	4.92	.38	7.79	8.47	1.11	29.2
70	4.69	.34	6.64	5.30	.44	8.94	9.12	1.29	33.5
75	5.03	.39	7.55	5.68	.50	10.2	9.77	1.48	38.0
80	5.36	.45	8.50	6.05	.57	11.4	10.4	1.7	42.8
85	5.70	.50	9.51	6.43	.64	12.8	11.1	1.9	47.9
90	6.03	.57	10.6	6.81	.72	13.9	11.7	2.1	53.3
95	6.37	.63	11.7	7.19	.80	15.7	12.4	2.4	58.9
100	6.70	.70	12.8	7.57	.89	17.3	13.0	2.6	64.7
110	7.37	.84	15.3	8.33	1.08	20.6	14.3	3.2	77.2
120	8.04	1.00	18.0	9.08	1.28	24.2	15.6	3.8	90.7
130	8.71	1.18	20.9	9.84	1.50	28.1	16.9	4.4	105
140	9.38	1.37	23.9	10.6	1.7	32.2	18.2	5.1	121
150	10.0	1.6	27.3	11.3	2.0	36.7	19.5	5.9	137
160	10.7	1.8	30.7	12.1	2.3	41.2	20.8	6.7	154
170	11.4	2.0	34.3	12.9	2.6	46.1	22.2	7.7	173
180	12.1	2.3	38.1	13.6	2.9	51.3	23.4	8.5	192
190	12.7	2.5	42.1	14.4	3.2	56.7	24.7	9.5	212
200	13.4	2.8	46.3	15.1	3.5	62.3	26.1	10.6	233
220	14.7	3.4	55.3	16.7	4.3	74.3	28.7	12.8	278
240	16.1	4.0	66.4	18.2	5.1	87.3	31.3	15.2	327
260	17.4	4.7	75.3	19.7	6.0	101	33.9	17.9	379
280	18.8	5.5	86.3	21.2	7.0	116	36.5	20.7	435
300	20.1	6.3	98.1	22.7	8.0	132	39.1	23.8	494
350	23.5	8.6	130	26.5	10.9	175	45.6	32.3	657
400	26.8	11.2	167	30.3	14.3	225	52.1	42.2	841
450	30.2	14.2	208	34.1	18.1	279			
500	33.5	17.4	252	37.9	22.3	340			

Friction Losses In Pipe; C=100 (For Old Pipe)
3 Inch

FLOW	Cast Iron			Std Wt Steel			Extra Strong Steel			Double Extra Strong Steel		
	3.0″ inside dia			3.068″ inside dia			2.900″ inside dia			2.300″ inside dia		
U S gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
10	.45	.00	.070	.43	.00	.063	.49	.00	.083	.77	.01	.256
15	.68	.01	.149	.65	.01	.134	.73	.01	.176	1.16	.02	.543
20	.91	.01	.254	.87	.01	.227	.97	.02	.299	1.54	.04	.924
25	1.13	.02	.383	1.09	.02	.344	1.21	.02	.452	1.98	.06	1.40
30	1.36	.03	.537	1.30	.03	.481	1.45	.03	.633	2.32	.08	1.96
35	1.59	.04	.714	1.52	.04	.640	1.70	.04	.842	2.70	.11	2.60
40	1.82	.05	.914	1.74	.05	.820	1.94	.06	1.08	3.09	.15	3.33
45	2.04	.06	1.14	1.95	.06	1.02	2.18	.07	1.34	3.47	.19	4.14
50	2.27	.08	1.38	2.17	.07	1.24	2.43	.09	1.63	3.86	.23	5.03
55	2.50	.10	1.64	2.39	.09	1.47	2.67	.11	1.94	4.25	.28	5.99
60	2.72	.12	1.94	2.60	.11	1.74	2.91	.13	2.28	4.63	.33	7.05
65	2.95	.14	2.24	2.82	.12	2.01	3.16	.15	2.65	5.02	.39	8.18
70	3.18	.16	2.57	3.04	.14	2.31	3.40	.18	3.04	5.40	.45	9.38
75	3.40	.18	2.92	3.25	.16	2.62	3.64	.21	3.45	5.79	.52	10.7
80	3.63	.20	3.30	3.47	.19	2.96	3.88	.23	3.89	6.18	.59	12.0
85	3.86	.23	3.69	3.69	.21	3.31	4.12	.26	4.35	6.56	.67	13.4
90	4.09	.26	4.10	3.91	.24	3.67	4.37	.29	4.83	6.95	.75	14.9
95	4.31	.29	4.53	4.12	.26	4.06	4.61	.33	5.34	7.34	.84	16.5
100	4.54	.32	4.98	4.34	.29	4.47	4.85	.36	5.87	7.72	.93	18.1
110	4.99	.39	5.94	4.77	.35	5.33	5.33	.44	7.01	8.49	1.12	21.6
120	5.45	.46	6.98	5.21	.42	6.26	5.81	.52	8.23	9.27	1.34	25.4
130	5.90	.54	8.09	5.64	.49	7.26	6.30	.62	9.54	10.0	1.6	29.5
140	6.35	.63	9.28	6.08	.57	8.32	6.79	.71	10.9	10.8	1.8	33.8
150	6.81	.72	10.6	6.51	.66	9.48	7.28	.82	12.5	11.6	2.1	38.5
160	7.26	.82	11.9	6.94	.75	10.7	7.76	.93	14.0	12.4	2.4	43.3
180	8.16	1.03	14.8	7.81	.95	13.2	8.72	1.01	17.4	13.9	3.0	52.6
200	9.08	1.28	18.0	8.68	1.17	16.1	9.70	1.46	21.2	15.4	3.7	65.4
220	9.99	1.55	21.4	9.55	1.42	19.2	10.7	1.78	25.3	17.0	4.5	78.0
240	10.9	1.8	25.2	10.4	1.7	22.6	11.6	2.07	29.7	18.5	5.3	91.6
260	11.8	2.2	29.2	11.3	2.0	26.2	12.6	2.46	34.4	20.1	6.3	106
280	12.7	2.5	33.5	12.2	2.3	30.0	13.6	2.88	39.5	21.6	7.3	122
300	13.6	2.9	38.0	13.0	2.6	34.1	14.5	3.26	44.8	23.2	8.4	138
320	14.5	3.3	42.8	13.9	3.0	38.4	15.5	3.77	50.5	24.7	9.5	156
340	15.4	3.7	47.9	14.8	3.4	43.0	16.5	4.22	56.5	26.3	10.7	175
360	16.3	4.1	53.3	15.6	3.8	47.8	17.5	4.73	62.8	27.8	12.0	194
380	17.3	4.6	58.9	16.5	4.2	52.8	18.4	5.27	69.4	29.3	13.3	214
400	18.2	5.1	64.7	17.4	4.7	58.0	19.4	5.81	76.3	30.9	14.8	236
420	19.1	5.7	70.8	18.2	5.1	63.5	20.4	6.43	83.5	32.4	16.3	258
440	20.0	6.2	77.2	19.1	5.7	69.2	21.4	7.13	91.1	34.0	18.0	281
460	20.9	6.8	83.8	20.0	6.2	75.3	22.3	7.75	98.9	35.5	19.6	305
480	21.8	7.4	90.7	20.8	6.7	81.3	23.3	8.37	107	37.1	21.4	330
500	22.7	8.0	97.8	21.7	7.3	87.7	24.2	9.15	115	38.6	23.2	356
550	25.0	9.7	117	23.9	8.9	105	26.7	11.1	138	42.5	28.1	425
600	27.2	11.5	137	26.0	10.5	123	29.1	13.1	162	46.3	33.3	499
650	29.5	13.5	159	28.2	12.4	143	31.6	15.5	187	50.2	39.0	579

Friction Losses In Pipe; C=100 (For Old Pipe)
3½ Inch

FLOW	Cast Iron			Std Wt Steel			Extra Strong Steel			Double Extra Strong Steel		
	3.5" inside dia			3.548" inside dia			3.364" inside dia			2.728" inside dia		
U S gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
15	.50	.00	.061	.49	.00	.058	.54	.00	.075	.82	.01	.208
20	.67	.01	.120	.65	.01	.112	.72	.01	.145	1 10	.02	.403
25	.84	.01	.181	.81	.01	.169	.90	.01	.220	1.37	.03	.609
30	1.00	.02	.254	.97	.01	.237	1.08	.02	.308	1.65	.04	.853
35	1.17	.02	.337	1.14	.02	.316	1.26	.02	.409	1.92	.06	1.13
40	1.34	.03	.432	1.30	.03	.404	1.44	.03	.524	2.20	.08	1.45
45	1.51	.04	.537	1.46	.03	.503	1.63	.04	.651	2.47	.10	1.81
50	1.67	.04	.653	1 62	.04	.611	1.80	.05	.791	2.74	.12	2.19
60	2.01	.06	.914	1.95	.06	.856	2.17	.07	1.11	3.29	.17	3.07
70	2.34	.09	1.22	2.27	.08	1.14	2.53	.10	1.47	3.84	.23	4.09
80	2.68	.11	1.56	2.60	.11	1.46	2.89	.13	1.89	4.39	.30	5.23
90	3.01	.14	1.94	2.92	.13	1.81	3.25	.16	2.35	4.94	.38	6.51
100	3.33	.17	2.35	3.25	.16	2.20	3.61	.20	2.85	5.49	.47	7.91
110	3.68	.21	2.81	3.57	.20	2.63	3.97	.24	3.40	6.04	.57	9.43
120	4.02	.25	3.30	3.99	.25	3.08	4.33	.29	4.00	6.59	.67	11.1
130	4.35	.29	3.82	4.22	.28	3.58	4.69	.34	4.64	7.13	.79	12.8
140	4.68	.34	4.38	4.54	.32	4.10	5.05	.40	5.32	7.68	.92	14.7
150	5.02	.39	4.99	4.87	.37	4.67	5.41	.45	6.05	8.23	1.05	16.8
160	5.35	.44	5.61	5.19	.42	5.25	5.78	.52	6.81	8.78	1.20	18.9
170	5.69	.50	6.28	5.52	.47	5.85	6.14	.59	7.61	9.33	1.35	21.1
180	6.02	.56	6.98	5.85	.53	6.53	6.50	.66	8.46	9.88	1.52	22.9
190	6.35	.63	7.71	6.17	.59	7.22	6.85	.73	9.35	10.4	1.7	25.9
200	6.69	.70	8.48	6.50	.66	7.94	7.22	.81	10.3	11.0	1.9	28.5
220	7.35	.84	10.1	7.14	.79	9.47	7.94	.98	12.3	12.1	2.3	34.0
240	8.03	1.00	11.9	7.79	.94	11.1	8.66	1.17	14.4	13.2	2.7	39.9
260	8.70	1.18	13.8	8.44	1.11	12.9	9.38	1.37	16.7	14.3	3.2	46.3
280	9.36	1.36	15.8	9.09	1.28	14.8	10.1	1.6	19.2	15.4	3.7	53.1
300	10.0	1.55	18.0	9.74	1.47	16.8	10.8	1.8	21.8	16.5	4.2	60.4
320	10.7	1.8	20.2	10.4	1.7	18.9	11.5	2.1	24.5	17.6	4.8	68.0
340	11.4	2.0	22.6	11.0	1.9	21.2	12.3	2.4	27.4	18.7	5.4	76.1
360	12.0	2.2	25.2	11.7	2.1	23.5	13.0	2.6	30.5	19.8	6.1	84.6
380	12.7	2.5	27.8	12.3	2.4	26.0	13.7	2.9	33.7	20.9	6.8	93.5
400	13.4	2.8	30.6	13.0	2.6	28.6	14.4	3.2	37.1	22.0	7.5	103
420	14.0	3.1	33.5	13.6	2.9	31.3	15.2	3.6	40.6	23.0	8.2	112
440	14.7	3.4	36.5	14.3	3.2	34.1	15.9	3.9	44.2	24.1	9.0	123
460	15.4	3.7	39.6	14.9	3.5	37.1	16.6	4.3	48.0	25.2	9.9	133
480	16.1	4.0	42.8	15.6	3.8	40.1	17.3	4.7	51.9	26.3	10.7	144
500	16.7	4.3	46.2	16.2	4.1	43.3	18.1	5.1	56.0	27.4	11.7	155
550	18.4	5.3	55.1	17.9	5.0	51.6	19.9	6.2	66.8	30.2	14.2	185
600	20.1	6.3	64.7	19.5	5.9	60.6	21.7	7.3	78.5	32.9	16.8	218
650	21.8	7.4	75.1	21.1	6.9	70.2	23.5	8.6	91.0	35.7	19.8	252
700	23.4	8.5	86.1	22.7	8.0	80.6	25.3	9.4	104	38.4	22.9	289
750	25.1	9.8	97.8	24.4	9.3	91.5	27.1	11.4	119	41.2	26.4	329
800	26.8	11.2	110	26.0	10.5	103	28.9	13.0	131	43.9	30.0	371
850	28.4	12.5	123	27.6	11.8	115	30.7	14.6	150	46.7	33.9	414

The National Bureau of Standards has recommended the elimination of this pipe size.

Friction Losses In Pipe; C=100 (For Old Pipe)
4 Inch

FLOW	Cast Iron			Std Wt Steel			Extra Strong Steel			Double Extra Strong Steel		
	4.0″ inside dia			4.026″ inside dia			3.826″ inside dia			3.152″ inside dia		
U S gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
20	.51	.00	.063	.50	.00	.061	.56	.00	.078	.82	.01	.199
30	.77	.01	.132	.76	.01	.128	.84	.01	.164	1.23	.02	.422
40	1.02	.02	.226	1.01	.02	.219	1.12	.02	.280	1.65	.04	.719
50	1.28	.03	.341	1.26	.03	.330	1.40	.03	.423	2.06	.07	1.09
60	1.53	.04	.477	1.51	.04	.463	1.67	.04	.593	2.47	.10	1.52
70	1.79	.05	.635	1.76	.05	.615	1.95	.06	.789	2.88	.13	2.02
80	2.04	.06	.813	2.02	.06	.788	2.23	.08	1.01	3.29	.17	2.59
90	2.30	.08	1.01	2.27	.08	.980	2.51	.10	1.26	3.70	.21	3.22
100	2.55	.10	1.23	2.52	.10	1.19	2.79	.12	1.53	4.11	.26	3.92
110	2.81	.12	1.47	2.77	.12	1.42	3.07	.15	1.82	4.52	.32	4.67
120	3.06	.15	1.72	3.02	.14	1.67	3.35	.17	2.14	4.94	.38	5.49
130	3.32	.17	2.00	3.28	.17	1.93	3.63	.20	2.48	5.35	.44	6.36
140	3.57	.20	2.29	3.53	.19	2.22	3.91	.24	2.84	5.76	.52	7.30
150	3.83	.23	2.61	3.78	.22	2.53	4.19	.27	3.24	6.17	.59	8.31
160	4.08	.26	2.93	4.03	.25	2.84	4.47	.31	3.64	6.58	.67	9.34
170	4.34	.29	3.28	4.29	.29	3.18	4.75	.35	4.07	6.99	.76	10.5
180	4.60	.33	3.64	4.54	.32	3.53	5.02	.39	4.52	7.40	.85	11.6
190	4.86	.37	4.03	4.79	.36	3.90	5.30	.44	5.00	7.82	.95	12.8
200	5.11	.41	4.43	5.05	.40	4.29	5.58	.48	5.50	8.23	1.05	14.1
220	5.62	.49	5.28	5.55	.48	5.12	6.14	.59	6.56	9.05	1.27	16.8
240	6.13	.58	6.21	6.05	.57	6.01	6.70	.70	7.70	9.87	1.51	19.8
260	6.64	.69	7.20	6.55	.67	6.97	7.26	.82	8.93	10.7	1.8	22.9
280	7.15	.79	8.25	7.06	.77	8.00	7.82	.95	10.2	11.5	2.1	26.3
300	7.66	.91	9.38	7.57	.89	9.09	8.38	1.09	11.6	12.3	2.4	29.9
320	8.17	1.04	10.6	8.07	1.01	10.2	8.94	1.24	13.1	13.2	2.7	33.7
340	8.68	1.17	11.8	8.58	1.14	11.5	9.50	1.40	14.7	14.0	3.0	37.7
360	9.19	1.31	13.1	9.08	1.28	12.7	10.0	1.6	16.3	14.8	3.4	41.9
380	9.70	1.46	14.5	9.59	1.43	14.1	10.6	1.7	18.0	15.6	3.8	46.3
400	10.2	1.6	16.0	10.1	1.6	15.5	11.2	1.9	19.8	16.5	4.2	50.9
420	10.7	1.8	17.5	10.6	1.7	16.9	11.7	2.1	21.7	17.3	4.7	55.7
440	11.2	1.9	19.0	11.1	1.9	18.5	12.3	2.3	23.6	18.1	5.1	60.7
460	11.7	2.1	20.7	11.6	2.1	20.0	12.8	2.5	25.7	18.9	5.6	65.9
480	12.3	2.3	22.4	12.1	2.3	21.7	13.4	2.8	27.8	19.7	6.0	71.3
500	12.8	2.5	24.1	12.6	2.5	23.4	14.0	3.0	30.0	20.6	6.6	76.9
550	14.0	3.0	28.8	13.9	3.0	27.9	15.3	3.6	35.7	22.6	7.9	91.7
600	15.3	3.6	33.8	15.1	3.5	32.8	16.7	4.3	42.0	24.7	9.5	108
650	16.6	4.3	39.2	16.4	4.2	38.0	18.1	5.1	48.7	26.7	11.1	125
700	17.9	5.0	45.0	17.6	4.8	43.6	19.5	5.9	55.8	28.8	12.9	143
750	19.2	5.7	51.1	18.9	5.6	49.5	20.9	6.8	63.4	30.8	14.7	163
800	20.4	6.5	57.6	20.2	6.3	55.8	22.3	7.7	71.5	32.9	16.8	183
850	21.7	7.3	64.4	21.4	7.1	62.4	23.7	8.7	79.9	35.0	19.0	205
900	23.0	8.2	71.6	22.7	8.0	69.3	25.1	9.8	88.9	37.0	21.3	228
950	24.3	9.2	79.1	24.0	9.0	76.6	26.5	10.9	98.2	39.1	23.8	252
1000	25.5	10.1	87.0	25.2	9.9	84.3	27.9	12.1	108	41.1	26.3	277
1100	28.1	12.3	104	27.7	11.9	101	30.7	14.6	129	45.2	31.7	331

Friction Losses In Pipe; C=100 (For Old Pipe)
5 Inch

FLOW	Cast Iron 5.0″ inside dia			Std Wt Steel 5.047″ inside dia			Extra Strong Steel 4.813″ inside dia			Double Extra Strong Steel 4.063″ inside dia		
US gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
30	.49	.00	.045	.48	.00	.043	.53	.00	.054	.75	.01	.124
40	.65	.01	.076	.64	.01	.073	.71	.01	.092	1.00	.02	.212
50	.82	.01	.115	.80	.01	.110	.88	.01	.139	1.24	.02	.320
60	.98	.01	.161	.96	.01	.154	1.06	.02	.194	1.49	.03	.448
70	1.14	.02	.214	1.12	.02	.205	1.23	.02	.258	1.74	.05	.596
80	1.31	.03	.275	1.28	.03	.262	1.41	.03	.330	1.99	.06	.763
90	1.47	.03	.341	1.44	.03	.326	1.59	.04	.411	2.24	.08	.948
100	1.63	.04	.415	1.60	.04	.396	1.76	.05	.499	2.49	.10	1.15
120	1.96	.06	.581	1.92	.06	.555	2.11	.07	.700	2.98	.14	1.61
140	2.29	.08	.773	2.24	.08	.739	2.47	.09	.931	3.48	.19	2.15
160	2.61	.11	.990	2.56	.10	.946	2.82	.12	1.19	3.98	.25	2.75
180	2.94	.13	1.23	2.88	.13	1.18	3.17	.16	1.48	4.48	.31	3.41
200	3.27	.16	1.50	3.20	.16	1.43	3.52	.19	1.80	4.98	.39	4.15
220	3.59	.20	1.78	3.52	.20	1.70	3.88	.23	2.15	5.47	.47	4.95
240	3.92	.24	2.10	3.85	.23	2.00	4.23	.28	2.52	5.97	.55	5.82
260	4.25	.28	2.43	4.17	.27	2.32	4.58	.33	2.92	6.47	.65	6.75
280	4.58	.33	2.79	4.49	.31	2.66	4.94	.38	3.35	6.97	.76	7.74
300	4.90	.38	3.17	4.81	.36	3.03	5.29	.43	3.81	7.46	.87	8.79
320	5.23	.43	3.57	5.13	.41	3.41	5.64	.49	4.29	7.96	.98	9.91
340	5.56	.48	3.99	5.45	.46	3.81	5.99	.56	4.80	8.46	1.11	11.1
360	5.89	.54	4.44	5.77	.52	4.24	6.35	.63	5.34	8.96	1.25	12.3
380	6.22	.60	4.90	6.09	.58	4.68	6.70	.70	5.90	9.45	1.39	13.6
400	6.54	.66	5.39	6.41	.64	5.15	7.05	.77	6.49	9.95	1.54	15.0
420	6.87	.73	5.90	6.73	.70	5.64	7.40	.85	7.10	10.4	1.7	16.4
440	7.20	.81	6.43	7.05	.77	6.14	7.76	.94	7.74	10.9	1.8	17.8
460	7.52	.88	6.98	7.38	.85	6.67	8.11	1.02	8.40	11.4	2.0	19.4
480	7.85	.96	7.55	7.70	.92	7.22	8.46	1.11	9.09	11.9	2.2	21.0
500	8.17	1.04	8.15	8.02	1.00	7.79	8.82	1.21	9.81	12.4	2.4	22.6
650	8.99	1.26	9.72	8.82	1.21	9.28	9.70	1.46	11.7	13.7	2.9	27.0
600	9.80	1.49	11.7	9.62	1.49	10.9	10.6	1.7	13.7	14.9	3.5	31.7
650	10.6	1.7	13.2	10.4	1.7	12.6	11.5	2.1	15.9	16.2	4.1	36.8
700	11.4	2.0	15.2	11.2	1.9	14.5	12.3	2.4	18.3	17.4	4.7	42.2
750	12.3	2.4	17.2	12.0	2.2	16.5	13.2	2.7	20.8	18.7	5.4	47.9
800	13.1	2.7	19.4	12.8	2.5	18.6	14.1	3.1	23.4	19.9	6.2	54.0
850	13.9	3.0	21.7	13.6	2.9	20.8	15.0	3.5	26.2	21.1	6.9	60.4
900	14.7	3.4	24.2	14.4	3.2	23.1	15.9	3.9	29.1	22.4	7.8	67.1
950	15.5	3.7	26.7	15.2	3.6	25.5	16.7	4.3	32.2	23.6	8.7	75.9
1000	16.3	4.1	29.4	16.0	4.0	28.1	17.6	4.8	35.4	24.9	9.6	81.6
1100	18.0	5.0	35.0	17.6	4.8	33.5	19.4	5.8	42.2	27.4	11.7	97.3
1200	19.6	6.0	41.1	19.2	5.7	39.3	21.1	6.9	49.5	29.8	13.8	114
1300	21.2	7.0	47.7	20.8	6.7	45.6	22.9	8.2	57.4	32.3	16.2	133
1400	22.9	8.1	54.7	22.4	7.8	52.3	24.7	9.5	65.9	34.8	18.8	152
1500	24.5	9.3	62.2	24.0	9.0	59.4	26.4	10.8	74.8	37.3	21.6	173
1600	26.1	10.6	70.1	25.6	10.2	66.9	28.2	12.4	84.3	39.8	24.6	195
1700	27.8	12.0	78.4	27.2	11.5	74.9	30.0	14.0	94.4	42.3	27.8	218

Friction Losses In Pipe; C = 100 (For Old Pipe)
6 Inch

FLOW	Cast Iron			Std Wt Steel			Extra Strong Steel			Double Extra Strong Steel		
	6.0″ inside dia			6.065″ inside dia			5.761″ inside dia			4.897″ inside dia		
US gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
50	.57	.01	.047	.56	.00	.045	.62	.01	.058	.85	.01	.127
60	.68	.01	.066	.67	.01	.063	.74	.01	.081	1.02	.02	.178
70	.79	.01	.088	.78	.01	.084	.86	.01	.108	1.19	.02	.237
80	.91	.01	.113	.89	.01	.107	.98	.01	.138	1.36	.03	.304
90	1.02	.02	.141	1.00	.02	.133	1.11	.02	.171	1.53	.04	.378
100	1.13	.02	.171	1.11	.02	.162	1.23	.02	.208	1.70	.05	.459
120	1.36	.03	.239	1.33	.03	.227	1.48	.03	.292	2.04	.06	.643
140	1.59	.04	.318	1.56	.04	.302	1.72	.05	.388	2.38	.09	.855
160	1 82	.05	.408	1.78	.05	.387	1.97	.06	.497	2.72	.12	1.10
180	2.04	.06	.507	2.00	.06	.481	2.22	.08	.618	3.06	.15	1.36
200	2.27	.08	.616	2.22	.08	.584	2.46	.09	.751	3.40	.18	1.65
220	2.50	.10	.735	2.44	.09	.697	2.71	.11	.895	3.74	.22	1.97
240	2.72	.12	.863	2.67	.11	.819	2.96	.14	1.03	4.08	.26	2.32
260	2.95	.14	1.00	2.89	.13	.950	3.20	.16	1.22	4.42	.30	2.69
280	3.18	.16	1.15	3.11	.15	1.09	3.45	.19	1.40	4.77	.35	3.08
300	3.40	.18	1.30	3.33	.17	1.24	3.69	.21	1.59	5.11	.41	3.50
320	3.64	.21	1.47	3.56	.20	1.39	3.94	.24	1.79	5.45	.46	3.95
340	3.86	.23	1.64	3.78	.22	1.56	4.19	.27	2.00	5.79	.52	4.42
360	4.08	.26	1.83	4.00	.25	1.73	4.43	.31	2.23	6.13	.58	4.91
380	4.31	.29	2.02	4.22	.28	1.92	4.68	.34	2.46	6.47	.65	5.43
400	4.55	.32	2.22	4.44	.31	2.11	4.93	.38	2.71	6.81	.72	5.97
450	5.11	.41	2.76	5.00	.39	2.62	5.54	.48	3.36	7.66	.91	7.42
500	5.68	.50	3.36	5.56	.48	3.19	6.16	.59	4.09	8.51	1.13	9.02
550	6.25	.61	4.00	6.11	.58	3.80	6.77	.71	4.88	9.37	1.36	10.8
600	6.81	.72	4.70	6.66	.69	4.46	7.39	.85	5.73	10.2	1.6	12.6
650	7.38	.85	5.45	7.22	.81	5.17	8.00	.99	6.64	11.1	1.9	14.6
700	7.95	.98	6.25	7.78	.94	5.93	8.63	1.16	7.62	11.9	2.2	16.8
750	8.52	1.13	7.10	8.34	1.08	6.74	9.24	1.33	8.66	12.8	2.5	19.1
800	9.08	1.28	8.00	8.90	1.23	7.60	9.85	1.51	9.75	13.6	2.9	21.5
850	9.65	1.45	8.95	9.45	1.39	8.50	10.5	1.7	10.9	14.5	3.3	24.1
900	10.2	1.6	9.95	10.0	1.6	9.44	11.1	1.9	12.1	15.3	3.7	26.7
950	10.8	1.8	11.0	10.5	1.7	10.2	11.7	2.1	13.4	16.2	4.1	29.6
1000	11.4	2.0	12.1	11.1	1.9	11.5	12.3	2.4	14.7	17.0	4.5	32.5
1100	12.5	2.4	14.4	12.2	2.3	13.7	13.5	2.8	17.6	18.7	5.4	38.8
1200	13.6	2.9	16.9	13.3	2.7	16.1	14.8	3.4	20.7	20.4	4.5	45.5
1300	14.8	3.4	19.7	14.4	3.2	18.6	16.0	4.0	23.9	22.1	7.6	52.8
1400	15.9	3.9	22.5	15.6	3.8	21.4	17.2	4.6	27.5	23.8	8.8	60.6
1500	17.0	4.5	25.6	16.7	4.3	24.3	18.5	5.3	31.2	25.5	10.1	68.8
1600	18.2	5.1	28.9	17.8	4.9	27.4	19.7	6.0	35.2	27.2	11.5	77.5
1700	19.3	5.8	32.3	18.9	5.6	30.6	20.9	6.8	39.4	28.9	13.0	86.8
1800	20.4	6.5	35.9	20.0	6.2	34.0	22.2	7.7	43.7	30.6	14.6	96.4
1900	21.5	7.2	39.7	21.1	6.9	37.6	23.4	8.4	48.3	32.3	16.2	107
2000	22.7	8.0	43.6	22.2	7.7	41.4	24.6	9.4	53.1	34.0	18.0	117
2200	25.0	9.7	52.0	24.4	9.3	49.4	27.1	11.4	63.4	37.4	21.7	140
2400	27.2	11.5	61.1	26.7	11.1	58.0	29.6	13.6	74.5	40.8	25.9	164

Friction Losses In Pipe; C = 100 (For Old Pipe)
8 Inch

FLOW US gal per min	Cast Iron 8.0″ inside dia			Std Wt Steel 7.981″ inside dia			Extra Strong Steel 7.625″ inside dia			Double Extra Strong Steel. 6.875″ inside dia		
	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
130	.83	.01	.069	.83	.01	.069	.91	.01	.087	1.12	.02	.143
140	.90	.01	.079	.90	.01	.079	.98	.01	.099	1.21	.02	.164
150	.96	.01	.089	.96	.01	.091	1.05	.02	.116	1.30	.03	.187
160	1.02	.02	.101	1.03	.02	.102	1.12	.02	.127	1.38	.03	.210
170	1.08	.02	.112	1.09	.02	.114	1.19	.02	.142	1.47	.03	.235
180	1.15	.02	.125	1.15	.02	.126	1.26	.02	.158	1.56	.04	.261
190	1.21	.02	.138	1.22	.02	.140	1.33	.03	.175	1.64	.04	.289
200	1.28	.03	.152	1.28	.03	.154	1.41	.03	.192	1.73	.05	.318
220	1.40	.03	.181	1.41	.03	.183	1.55	.04	.229	1.90	.06	.379
240	1.53	.04	.213	1.54	.04	.215	1.69	.04	.269	2.07	.07	.445
260	1.66	.04	.247	1.67	.04	.250	1.83	.05	.312	2.25	.08	.516
280	1.79	.05	.283	1.80	.05	.286	1.97	.06	.358	2.42	.09	.592
300	1.91	.06	.322	1.92	.06	.325	2.11	.07	.406	2.59	.10	.672
350	2.24	.08	.428	2.24	.08	.433	2.46	.09	.540	3.02	.14	.894
400	2.56	.10	.548	2.57	.10	.554	2.81	.12	.692	3.46	.19	1.14
450	2.87	.13	.681	2.88	.13	.689	3.16	.15	.860	3.89	.24	1.42
500	3.19	.16	.828	3.20	.16	.838	3.51	.19	1.05	4.32	.29	1.73
550	3.51	.19	.987	3.52	.19	.999	3.86	.23	1.25	4.75	.35	2.06
600	3.83	.23	1.16	3.85	.23	1.17	4.22	.28	1.46	5.19	.42	2.42
650	4.15	.27	1.34	4.17	.27	1.36	4.57	.32	1.70	5.62	.49	2.78
700	4.47	.31	1.54	4.49	.31	1.56	4.92	.38	1.95	6.05	.57	3.22
750	4.79	.36	1.75	4.81	.36	1.77	5.27	.43	2.21	6.49	.65	3.66
800	5.11	.41	1.97	5.13	.41	1.99	5.62	.49	2.49	6.91	.74	4.13
850	5.43	.46	2.21	5.45	.46	2.23	5.97	.55	2.79	7.35	.84	4.62
900	5.75	.51	2.46	5.77	.52	2.48	6.32	.62	3.10	7.78	.94	5.13
950	6.06	.57	2.71	6.09	.58	2.74	6.67	.69	3.43	8.21	1.05	5.67
1000	6.38	.63	2.98	6.41	.64	3.02	7.03	.77	3.77	8.64	1.16	6.24
1100	7.03	.77	3.56	7.05	.77	3.60	7.83	.95	4.49	9.50	1.40	7.44
1200	7.66	.91	4.18	7.69	.92	4.23	8.43	1.10	5.28	10.4	1.7	8.74
1300	8.30	1.07	4.85	8.33	1.08	4.90	9.13	1.30	6.12	11.2	2.0	10.4
1400	8.95	1.24	5.56	8.97	1.25	5.62	9.83	1.50	7.02	12.1	2.3	11.6
1500	9.58	1.43	6.32	9.61	1.44	6.39	10.5	1.7	7.98	13.0	2.6	13.2
1600	10.2	1.6	7.12	10.3	1.7	7.20	11.2	2.0	8.99	13.8	3.0	14.9
1800	11.5	2.1	8.85	11.5	2.1	8.95	12.6	2.5	11.2	15.6	3.8	18.5
2000	12.8	2.6	10.8	12.8	2.5	10.9	14.1	3.1	13.6	17.3	4.7	22.5
2200	14.1	3.1	12.8	14.1	3.1	13.0	15.5	3.7	16.6	19.0	5.6	26.8
2400	15.3	3.6	15.1	15.4	3.7	15.2	16.9	4.4	19.0	20.7	6.7	31.5
2600	16.6	4.3	17.5	16.7	4.3	17.7	18.3	5.2	22.1	22.5	7.9	36.5
2800	17.9	5.0	20.0	18.0	5.0	20.3	19.7	6.0	25.3	24.2	9.1	41.9
3000	19.1	5.7	22.8	19.2	5.7	23.0	21.1	6.9	28.8	25.9	10.4	47.6
3500	22.4	7.8	30.3	22.4	7.8	30.6	24.6	9.4	38.3	30.2	14.2	63.3
4000	25.6	10.2	38.8	25.6	10.2	39.2	28.1	12.3	49.0	34.6	18.6	81.0
4500	28.7	12.8	48.2	28.8	12.9	48.8	31.6	15.5	60.9	38.9	23.5	101
5000	31.9	15.8	58.6	32.0	15.9	59.3	35.1	19.1	74.0	43.2	29.0	122
5500	35.1	19.1	69.9	35.3	19.4	70.7	38.6	23.2	88.3	47.5	35.1	146

Friction Losses In Pipe; C = 100 (For Old Pipe)
10 Inch

FLOW	Cast Iron			Standard Wt Steel			Fxtra Strong Steel		
	10.0″ inside dia			10.02″ inside dia			9.750″ inside dia		
US gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
180	.74	.01	.042	.73	.01	.042	.77	.01	.048
200	.82	.01	.051	.81	.01	.051	.86	.01	.058
220	.90	.01	.061	.89	.01	.061	.95	.01	.069
240	.98	.01	.072	.98	.01	.071	1.03	.02	.081
260	1.06	.02	.083	1.06	.02	.083	1.12	.02	.094
280	1.14	.02	.096	1.14	.02	.095	1.20	.02	.108
300	1.22	.02	.109	1.22	.02	.108	1.29	.03	.123
350	1.43	.03	.144	1.42	.03	.143	1.50	.04	.163
400	1.63	.04	.185	1.63	.04	.183	1.72	.05	.209
450	1.84	.05	.230	1.83	.05	.228	1.93	.06	.260
500	2.04	.06	.280	2.04	.06	.277	2.15	.07	.316
550	2.24	.08	.333	2.24	.08	.330	2.36	.09	.377
600	2.45	.09	.392	2.44	.09	.388	2.58	.10	.443
650	2.65	.11	.454	2.64	.11	.450	2.79	.12	.514
700	2.86	.13	.521	2.85	.13	.516	3.01	.14	.589
800	3.26	.17	.667	3.25	.16	.660	3.46	.19	.754
900	3.67	.21	.829	3.66	.21	.821	3.87	.23	.938
1000	4.08	.26	1.01	4.07	.26	.998	4.30	.29	1.14
1100	4.49	.31	1.20	4.48	.31	1.19	4.73	.35	1.36
1200	4.90	.37	1.41	4.89	.37	1.40	5.16	.41	1.60
1300	5.31	.44	1.64	5.30	.44	1.62	5.59	.49	1.85
1400	5.71	.51	1.88	5.70	.50	1.86	6.01	.56	2.12
1500	6.12	.58	2.13	6.10	.58	2.11	6.44	.64	2.41
1600	6.53	.66	2.40	6.51	.66	2.38	6.88	.74	2.72
1700	6.94	.75	2.69	6.92	.74	2.66	7.30	.83	3.04
1800	7.35	.84	2.99	7.32	.83	2.96	7.74	.93	3.38
1900	7.76	.94	3.30	7.73	.93	3.27	8.16	1.03	3.74
2000	8.16	1.03	3.63	8.14	1.03	3.60	8.60	1.15	4.11
2200	8.98	1.25	4.33	8.95	1.24	4.29	9.45	1.39	4.90
2400	9.80	1.49	5.09	9.76	1.48	5.04	10.3	1.6	5.76
2600	10.6	1.7	5.90	10.6	1.7	5.84	11.2	1.9	6.67
2800	11.4	2.0	6.77	11.4	2.0	6.70	12.0	2.2	7.65
3000	12.2	2.3	7.69	12.2	2.3	7.61	12.9	2.6	8.70
3200	13.1	2.7	8.66	13.0	2.7	8.58	13.8	3.0	9.80
3400	13.9	3.0	9.69	13.8	3.0	9.60	14.6	3.3	11.0
3600	14.7	3.4	10.8	14.6	3.3	10.7	15.5	3.7	12.2
3800	15.5	3.7	11.9	15.5	3.7	11.8	16.3	4.1	13.5
4000	16.3	4.1	13.1	16.3	4.1	13.0	17.2	4.6	14.8
4500	18.4	5.3	16.3	18.3	5.2	16.1	19.3	5.8	18.4
5000	20.4	6.5	19.8	20.3	6.4	19.6	21.5	7.2	22.4
5500	22.4	7.8	23.6	22.4	7.8	23.4	23.6	8.7	26.7
6000	24.5	9.3	27.7	24.4	9.3	27.5	25.8	10.3	31.4
6500	26.5	10.9	32.1	26.4	10.8	31.8	27.9	12.1	36.4
7000	28.6	12.7	36.9	28.5	12.6	36.5	30.1	14.1	41.7
7500	30.6	14.6	41.9	30.5	14.5	41.5	32.2	16.1	47.4

Friction Losses In Pipe; C=100 (For Old Pipe)
12 Inch

FLOW	Cast Iron			Standard Wt Steel			Extra Strong Steel		
	12.0″ inside dia			12.000″ inside dia			11.750″ inside dia		
US gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
200	.57	.01	.021	.57	.01	.021	.59	.01	.023
250	.71	.01	.032	.71	.01	.032	.74	.01	.035
300	.85	.01	.045	.85	.01	.045	.89	.01	.050
350	.99	.02	.059	.99	.02	.059	1.03	.02	.066
400	1.14	.02	.076	1.14	.02	.076	1.18	.02	.084
450	1.28	.03	.095	1.28	.03	.095	1.33	.03	.105
500	1.42	.03	.115	1.42	.03	.115	1.48	.03	.128
550	1.56	.04	.137	1.56	.04	.137	1.63	.04	.152
600	1.70	.05	.161	1.70	.05	.161	1.77	.05	.179
700	1.99	.06	.214	1.99	.06	.214	2.07	.07	.238
800	2.27	.08	.275	2.27	.08	.275	2.37	.09	.304
900	2.56	.10	.341	2.56	.10	.341	2.66	.11	.378
1000	2 84	.13	.415	2.84	.13	.415	2.96	.14	.460
1100	3.12	.15	.495	3.12	.15	.495	3.25	.16	.548
1200	3.41	.18	.581	3.41	.18	.581	3.55	.20	.644
1300	3.69	.21	.674	3.69	.21	.674	3.84	.23	.747
1400	3.98	.25	.773	3.98	.25	.773	4.14	.27	.857
1500	4.26	.28	.878	4.26	.28	.878	4.44	.31	.973
1600	4.55	.32	.990	4.55	.32	.990	4.73	.35	1.10
1800	5.11	.41	1.23	5.11	.41	1.23	5.33	.44	1.36
2000	5.68	.50	1.50	5.68	.50	1.50	5.92	.54	1.66
2200	6.25	.61	1.78	6.25	.61	1.78	6.51	.66	1.98
2400	6.81	.72	2.10	6.81	.72	2.10	7.10	.78	2.32
2600	7.38	.85	2.43	7.38	.85	2.43	7.69	.92	2.69
2800	7.95	.98	2.78	7.95	.98	2.78	8.28	1.07	3.09
3000	8.52	1.13	3.17	8.52	1.13	3.17	8 88	1.23	3.51
3500	9.95	1.54	4.21	9.95	1.54	4.21	10.3	1.6	4.67
4000	11.4	2.0	5.39	11.4	2.0	5.39	11.8	2.2	5.97
4500	12.8	2.5	6.70	12.8	2.5	6.70	13.3	2.7	7.43
5000	14.2	3.1	8.15	14.2	3.1	8.15	14.8	3.4	9.03
5500	15.6	3.8	9.72	15.6	3.8	9.72	16.3	4.1	10.8
6000	17 0	4.5	11.4	17.0	4.5	11.4	17.7	4.9	12.6
6500	18.4	5.3	13.2	18.4	5.3	13.2	19.2	5.7	14.7
7000	19.9	6.2	15.2	19.9	6.2	15.2	20.7	6.7	16.8
7500	21.3	7.1	17.3	21.3	7.1	17.3	22.2	7.7	19.1
8000	22.7	8.0	19.4	22.7	8.0	19.4	23.7	8.7	21.5
8500	24.2	9.1	21.7	24.2	9.1	21.7	25.1	9.8	24.1
9000	25.6	10.2	24.2	25.6	10.2	24.2	26.6	11.0	26.8
9500	27.0	11.3	26.7	27.0	11.3	26.7	28.1	12.3	29.6
10000	28.4	12.5	29.4	28.4	12.5	29.4	29.6	13.6	32.5
11000	31.2	15.1	35.0	31.2	15.1	35.0	32.5	16.4	38.8
12000	34.1	18 1	41.2	34 1	18.1	41.2	35 5	19 6	45.6
13000	36.9	21.2	47.7	36.9	21.2	47.7	38.4	22.9	52.9
14000	39.8	24.6	54.7	39.8	24.6	54.7	41.4	26.6	60.6
15000	42.6	28.2	62.2	42.6	28.2	62.2	44.4	30.6	68.9

Friction Losses In Pipe; C=100 (For Old Pipe)

14 Inch / 16 Inch

FLOW	Cast Iron			Steel			FLOW	Cast Iron			Steel		
	14.0″ inside dia			13.25″ inside dia				16.0″ inside dia			15.25″ inside dia		
US gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	US gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
300	.63	.01	.021	.70	.01	.028	500	.80	.01	.028	.88	.01	.036
400	.84	.01	.036	.93	.01	.047	600	.96	.01	.040	1.05	.02	.050
500	1.04	.02	.054	1.16	.02	.071	700	1.12	.02	.053	1.23	.02	.067
600	1.25	.02	.076	1.40	.03	.100	800	1.28	.03	.068	1.41	.03	.086
700	1.46	.03	.101	1.63	.04	.132	900	1.44	.03	.084	1.58	.04	.106
800	1.67	.04	.130	1.86	.05	.170	1000	1.60	.04	.102	1.76	.05	.129
900	1.88	.05	.161	2.09	.07	.211	1200	1.92	.06	.143	2.11	.07	.181
1000	2.09	.07	.196	2.33	.08	.256	1400	2.24	.08	.191	2.46	.09	.241
1100	2.30	.08	.234	2.56	.10	.306	1600	2.56	.10	.250	2.81	.12	.308
1200	2.50	.10	.275	2.79	.12	.359	1800	2.87	.13	.304	3.16	.16	.383
1300	2.71	.11	.318	3.02	.14	.416	2000	3.19	.16	.369	3.51	.19	.466
1400	2.92	.13	.365	3.26	.17	.477	2500	3.99	.25	.557	4.39	.30	.704
1500	3.13	.15	.415	3.49	.19	.542	3000	4.79	.36	.781	5.27	.43	.987
1600	3.34	.17	.478	3.72	.22	.611	3500	5.58	.48	1.06	6.15	.59	1.31
1700	3.54	.19	.523	3.95	.24	.684	4000	6.38	.63	1.33	7.03	.77	1.68
1800	3.75	.22	.581	4.19	.27	.760	4500	7.18	.80	1.65	7.91	.97	2.09
1900	3.96	.24	.643	4.42	.30	.840	5000	7.98	.99	2.01	8.79	1.2	2.54
2000	4.17	.27	.706	4.65	.34	.924	6000	9.58	1.43	2.82	10.5	1.7	3.56
2500	5.22	.42	1.07	5.81	.52	1.40	7000	11.2	1.9	3.75	12.3	2.4	4.73
3000	6.26	.61	1.50	6.98	.76	1.96	8000	12.8	2.5	4.79	14.1	3.1	6.06
3500	7.30	.83	1.99	8.15	1.03	2.60	9000	14.4	3.2	5.96	15.8	3.9	7.53
4000	8.34	1.08	2.55	9.31	1.35	3.32	10000	16.0	4.0	7.25	17.6	4.8	9.15
4500	9.4	1.37	3.17	10.5	1.7	4.13	11000	17.6	4.8	8.64	19.3	5.8	10.9
5000	10.4	1.7	3.85	11.6	2.1	5.03	12000	19.2	5.7	10.2	21.1	6.9	12.8
6000	12.5	2.4	5.39	14.0	3.0	7.05	13000	20.8	6.7	11.8	22.8	8.1	14.9
7000	14.6	3.3	7.17	16.3	4.1	9.38	14000	22.4	7.8	13.5	24.6	9.4	17.1
8000	16.7	4.3	9.18	18.6	5.4	12.0	15000	24.0	9.0	15.3	26.3	10.7	19.2
9000	18.8	5.5	11.4	20.9	6.8	14.9	16000	25.6	10.2	17.3	28.1	12.3	21.8
10000	20.9	6.8	13.9	23.3	8.4	18.1	18000	28.7	12.8	21.5	31.6	15.5	27.1
11000	23.0	8.2	16.5	25.6	10.2	21.6	20000	31.9	15.8	26.1	35.1	19.1	33.0
12000	25.0	9.7	19.4	27.9	12.1	25.4	22000	35.1	19.1	31.2	38.7	23.3	39.3
13000	27.1	11.4	22.5	30.2	14.2	29.5	24000	38.3	22.8	36.6	42.2	27.7	46.2
14000	29.2	13.3	25.9	32.6	16.5	33.8	25000	39.9	24.7	38.6	43.9	30.0	49.9
15000	31.3	15.2	29.4	34.9	18.9	38.4	26000	41.5	26.8	42.4	45.7	32.6	53.6
16000	33.4	17.3	33.1	37.2	21.5	43.3	28000	44.7	31.1	48.7	49.2	37.6	61.5
17000	35.4	19.5	37.0	39.5	24.2	48.4	30000	47.9	35.7	55.3	52.7	43.2	69.8
18000	37.5	21.6	41.2	41.9	27.3	53.8	32000	51.1	40.5	62.3	56.2	49.1	78.7
20000	41.7	27.0	50.0	46.5	33.6	65.4	34000	54.3	46	69.9	59.8	55.6	88.3
22000	45.9	32.7	59.7	51.2	40.7	78.0	36000	57.5	51	77.5	63.3	62.3	97.6
24000	50.0	38.9	70.1	55.8	48.4	91.6	38000	60.7	57	85.6	66.8	69.3	108

Friction Losses In Pipe; C = 100 (For old pipe)

18 Inch

FLOW	Cast Iron 18.0″ inside dia			Steel 17.18″ inside dia		
U S gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
500	.63	.01	.016	.69	.01	.020
600	.72	.01	.022	.83	.01	.028
700	.89	.01	.030	.97	.01	.037
800	1.01	.02	.038	1.11	.02	.048
900	1.13	.02	.048	1.25	.02	.060
1000	1.26	.02	.058	1.38	.03	.072
1200	1.53	.04	.081	1.66	.04	.101
1400	1.78	.05	.108	1.94	.06	.135
1600	2.03	.06	.138	2.21	.08	.173
1800	2.27	.08	.171	2.49	.10	.215
2000	2.52	.10	.208	2.77	.12	.261
2500	3.15	.15	.314	3.46	.19	.394
3000	3.78	.22	.440	4.15	.27	.553
3500	4.41	.30	.586	4.85	.37	.735
4000	5.04	.39	.750	5.54	.48	.941
4500	5.67	.50	.932	6.23	.60	1.17
5000	6.30	.62	1.13	6.92	.74	1.42
6000	7.56	.89	1.59	8.31	1.1	1.99
7000	8.83	1.2	2.11	9.70	1.5	2.65
8000	10.1	1.6	2.70	11.1	1.9	3.39
9000	11.3	2.0	3.36	12.5	2.4	4.22
10000	12.6	2.5	4.08	13.8	3.0	5.12
12000	15.3	3.6	5.72	16.6	4.3	7.18
14000	17.8	4.9	7.61	19.4	5.8	9.55
16000	20.3	6.4	9.74	22.1	7.6	12.2
18000	22.7	8.0	12.1	24.9	9.6	15.2
20000	25.2	9.9	14.7	27.7	11.9	18.5
22000	27.7	11.9	17.6	30.3	14.3	22.0
24000	30.6	14.6	20.6	33.2	17.1	25.9
26000	32.8	16.7	23.9	36.0	20.1	30.0
28000	35.5	19.6	27.4	38.8	23.4	34.4
30000	37.8	22.2	31.2	41.5	26.8	39.1
32000	40.6	25.6	35.1	44.3	30.5	44.1
34000	42.8	28.5	39.4	47.1	34.5	49.4
36000	45.4	32.0	43.7	49.9	38.7	54.8
38000	47.9	35.7	48.3	52.6	43.0	60.6
40000	50.4	39.5	53.1	55.4	47.1	66.6
42000	52.9	43	58.1	58.2	52.6	72.9
44000	55.4	48	63.3	61.0	57.8	79.4
46000	58.0	52	68.7	63.7	63	86.3

20 Inch

FLOW	Cast Iron 20.0″ inside dia			Steel 19.18″ inside dia		
U S gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
800	.82	.01	.023	.89	.01	.028
1000	1.02	.02	.035	1.11	.02	.042
1200	1.23	.02	.048	1.33	.03	.059
1400	1.43	.03	.064	1.55	.04	.079
1500	1.64	.04	.082	1.78	.05	.101
1800	1.83	.05	.102	2.00	.06	.126
2000	2.04	.06	.125	2.22	.08	.153
2500	2.55	.10	.188	2.78	.12	.231
3000	3.06	.15	.264	3.33	.17	.323
3500	3.57	.20	.351	3.89	.24	.430
4000	4.08	.26	.449	4.45	.31	.551
5000	5.10	.40	.679	5.55	.48	.832
6000	6.13	.58	.951	6.67	.69	1.17
7000	7.15	.79	1.26	7.78	.94	1.55
8000	8.17	1.0	1.62	8.89	1.2	1.98
10000	10.2	1.6	2.45	11.1	1.9	3.00
12000	12.3	2.4	3.43	13.3	2.7	4.20
14000	14.3	3.2	4.56	15.5	3.7	5.59
15000	15.3	3.6	5.18	16.7	4.3	6.35
16000	16.3	4.1	5.84	17.8	4.9	7.15
18000	18.4	5.3	7.26	20.0	6.2	8.90
20000	20.4	6.5	8.82	22.2	7.7	10.8
22000	22.5	7.9	10.5	24.4	9.3	12.9
24000	24.5	9.3	12.4	26.7	11.1	15.1
25000	25.5	10.1	13.3	27.8	12.0	16.3
26000	26.6	11.0	14.3	28.9	13.0	17.6
28000	28.6	12.7	16.4	31.1	15.0	20.1
30000	30.6	14.6	18.7	33.3	17.2	22.9
32000	32.6	16.5	21.0	35.6	19.7	25.8
34000	34.7	18.7	23.6	37.8	22.2	28.9
35000	35.7	19.8	24.8	38.9	23.5	30.4
36000	36.8	21.0	26.2	40.0	24.9	32.1
38000	38.8	23.4	28.9	42.2	27.7	35.4
40000	40.8	25.9	31.8	44.5	30.8	39.0
45000	45.9	32.7	39.5	50.0	38.9	48.5
50000	51.0	40	48.0	55.5	47.9	58.9
55000	56.1	49	57.3	61.1	58	70.3
60000	61.3	58	67.2	66.7	69	82.3
65000	66.4	68	78.1	72.2	81	95.7
70000	71.5	79	89.5	77.8	94	110

Friction Losses In Pipe; C=100 (For old pipe)

24 in. inside dia					30 in. inside dia				
Discharge in U S gallons per min	Discharge in U S gallons per 24 hr	Velocity feet per sec	Velocity head in ft	Head loss in feet per 100 ft	Discharge in U S gallons per min	Discharge in U S gallons per 24 hr	Velocity feet per sec	Velocity head in ft	Head loss in feet per 100 ft
350	505,000	.252	.00	.002	700	1,008,000	.322	.00	.002
700	1,008,000	.495	.00	.007	1000	1,440,000	.45	.00	.004
1000	1,440,000	.712	.01	.014	1300	1,872,000	.59	.01	.008
1400	2,016,000	.999	.01	.026	1700	2,448,000	.78	.01	.013
1700	2,448,000	1.21	.02	.038	2000	2,880,000	.91	.01	.017
2000	2,880,000	1.42	.03	.051	2400	3,456,000	1.095	.02	.023
2400	3,456,000	1.70	.045	.071	2700	3,888,000	1.23	.02	.030
2700	3,888,000	1.92	.06	.089	3100	4,464,000	1.43	.03	.039
3100	4,464,000	2.21	.08	.114	3400	4,896,000	1.55	.04	.046
3400	4,896,000	2.41	.09	.136	3800	5,472,000	1.74	.05	.057
3800	5,472,000	2.7	.113	.167	4100	5,904,000	1.87	.06	.065
4200	6,048,000	2.99	.13	.200	4500	6,480,000	2.05	.07	.077
4500	6,480,000	3.20	.16	.226	4800	6,912,000	2.19	.08	.087
4800	6,912,000	3.41	.18	.255	5200	7,488,000	2.37	.09	.101
5200	7,488,000	3.69	.21	.298	5500	7,920,000	2.51	.10	.112
5500	7,920,000	3.91	.24	.329	5900	8,496,000	2.69	.11	.127
5900	8,496,000	4.19	.27	.377	6200	8,928,000	2.83	.12	.139
6200	8,928,000	4.41	.32	.413	6900	9,936,000	3.12	.15	.170
6500	9,360,000	4.62	.33	.450	7600	10,944,000	3.47	.18	.203
6900	9,936,000	4.90	.37	.502	8300	11,952,000	3.79	.22	.240
7600	10,944,000	5.40	.50	.603	9000	12,960,000	4.10	.26	.278
8300	11,952,000	5.90	.54	.713	9700	13,968,000	4.42	.306	.319
9000	12,960,000	6.4	.64	.82	10000	14,400,000	4.56	.325	.337
9700	13,968,000	6.9	.74	.95	11000	15,840,000	5.01	.392	.401
10000	14,400,000	7.11	.79	1.00	12000	17,280,000	5.47	.47	.473
11000	15,840,000	7.82	.95	1.19	12500	18,000,000	5.70	.51	.51
12000	17,280,000	8.55	1.14	1.40	13000	18,720,000	5.94	.55	.55
12500	18,000,000	8.86	1.22	1.52	14000	20,160,000	6.4	.64	.63
13000	18,720,000	9.25	1.34	1.63	15000	21,600,000	6.85	.73	.71
14000	20,160,000	9.95	1.54	1.86	16000	23,040,000	7.30	.83	.81
15000	21,600,000	10.63	1.77	2.11	18000	25,920,000	8.20	1.05	1.00
16000	23,040,000	11.38	2.02	2.42	19000	27,360,000	8.67	1.17	1.11
18000	25,920,000	12.80	2.57	2.98	20000	28,800,000	9.12	1.30	1.22
19000	27,360,000	13.50	2.85	3.28	24000	34,600,000	10.09	1.89	1.73
20000	28,800,000	14.20	3.16	3.61	28000	40,320,000	12.75	2.46	2.27

Factor for correcting to other pipe sizes				Factor for correcting to other pipe sizes			
Dia in	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Dia in	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
23	1.089	1.186	1.230	29	1.078	1.161	1.199
22	1.190	1.416	1.527	28	1.148	1.318	1.399
21	1.306	1.706	1.915	27	1.235	1.524	1.670
				26	1.331	1.773	1.961

Friction Losses In Pipe; C=100 (For old pipe)

36 in. inside dia

Discharge in U S gallons per min	Discharge in U S gallons per 24 hr	Velocity feet per sec	Velocity head in ft	Head loss in feet per 100 ft
1400	2,016,000	.44	.00	.004
1700	2,448,000	.53	.00	.005
2000	2,880,000	.63	.01	.007
2400	3,456,000	.75	.01	.010
2800	4,032,000	.88	.01	.015
3400	4,896,000	1.07	.02	.019
4000	5,760,000	1.26	.02	.026
4800	6,912,000	1.51	.04	.036
5600	8,064,000	1.76	.05	.048
6200	8,928,000	1.95	.06	.057
7000	10,080,000	2.20	.07	.072
7600	10,944,000	2.39	.09	.084
8300	11,952,000	2.61	.10	.098
9000	12,960,000	2.83	.12	.114
9700	13,968,000	3.05	.14	.131
10000	14,400,000	3.14	.16	.139
11000	15,840,000	3.46	.19	.164
12000	17,280,000	3.78	.22	.193
13000	18,720,000	4.09	.26	.226
14000	20,160,000	4.40	.30	.260
15000	21,600,000	4.71	.34	.294
16000	23,040,000	5.03	.39	.330
18000	25,920,000	5.66	.50	.412
19000	27,360,000	5.98	.56	.454
20000	28,800,000	6.30	.61	.504
21000	30,240,000	6.60	.67	.544
22000	31,680,000	6.92	.74	.590
23000	33,120,000	7.24	.81	.640
24000	34,560,000	7.55	.88	.695
26000	37,440,000	8.18	1.04	.806
28000	40,320,000	8.80	1.20	.935
30000	43,200,000	9.44	1.38	1.065
34000	48,960,000	10.70	1.77	1.340
38000	54,720,000	11.95	2.20	1.650
42000	60,480,000	13.20	2.70	1.990

42 in. inside dia

Discharge in U S gallons per min	Discharge in U S gallons per 24 hr	Velocity feet per sec	Velocity head in ft	Head loss in feet per 100 ft
2000	2,880,000	.46	.003	.003
2500	3,600,000	.58	.005	.005
3000	4,320,000	.70	.007	.007
3500	5,040,000	.81	.010	.009
4000	5,760,000	.92	.013	.012
4500	6,480,000	1.04	.016	.015
5000	7,200,000	1.16	.021	.018
6000	8,640,000	1.39	.030	.025
7000	10,080,000	1.62	.041	.033
8000	11,520,000	1.85	.053	.043
9000	12,960,000	2.08	.067	.053
10000	14,400,000	2.31	.083	.065
12000	17,280,000	2.78	.120	.092
14000	20,160.000	3.24	.163	.122
16000	23,040,000	3.70	.212	.157
18000	25,920,000	4.16	.269	.194
20000	28,800,000	4.62	.331	.238
22000	31,680,000	5.10	.404	.282
24000	34,560,000	5.55	.477	.332
26000	37,440,000	6.02	.561	.383
28000	40,320,000	6.48	.651	.432
30000	43,200,000	6.94	.748	.501
32000	46,080,000	7.40	.850	.566
34000	48,960,000	7.86	.9	.632
36000	51,840,000	8.33	1.07	.702
38000	54,720.000	8.80	1.20	.778
40000	57,600 000	9.25	1.32	.855
42000	60,480,000	9.72	1.46	.936
44000	63,360,000	10.18	1.61	1.013
46000	66,240,000	10.63	1.76	1.100
48000	69,020,000	11.10	1.92	1.194
50000	72,000,000	11.58	2.08	1.280
52000	74,880,000	12.01	2.25	1.380
54000	77,760,000	12.49	2.41	1.490
56000	80,540,000	12.93	2.60	1.600

Factor for correcting to other pipe sizes (36 in.)

Dia in	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
35	1.058	1.119	1.147
34	1.121	1.257	1.321
33	1.190	1.416	1.527
32	1.266	1.602	1.774

Factor for correcting to other pipe sizes (42 in.)

Dia in	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
41	1.049	1.101	1.124
40	1.102	1.216	1.268
39	1.160	1.345	1.434
38	1.222	1.492	1.627

Friction Losses In Pipe; C=100 (For old pipe)

48 in. inside dia.

Discharge in U S gallons per min	Discharge in U S gallons per 24 hr	Velocity feet per sec	Velocity head in ft	Head loss in feet per 100 ft
2000	2,880,000	.35	.002	**.003**
4000	5,760,000	.70	.008	**.006**
6000	8,640,000	1.05	.017	**.012**
8000	11,520,000	1.40	.030	**.022**
10000	14,400,000	1.76	.048	**.034**
12000	17,280,000	2.11	.069	**.048**
14000	20,160,000	2.47	.095	**.064**
16000	23,040,000	2.83	.124	**.081**
18000	25,920,000	3.18	.156	**.101**
20000	28,800,000	3.53	.193	**.123**
22000	31,680,000	3.89	.235	**.147**
24000	34,560,000	4.24	.279	**.173**
26000	37,440,000	4.60	.329	**.201**
28000	40,320,000	4.96	.383	**.231**
30000	43,200,000	5.32	.440	**.262**
32000	46,080,000	5.68	.500	**.296**
34000	48,960,000	6.03	.565	**.331**
36000	51,840,000	6.39	.632	**.368**
38000	54,720,000	6.75	.708	**.406**
40000	57,600,000	7.10	.782	**.445**
42000	60,480,000	7.44	.859	**.487**
44000	63,360,000	7.80	.943	**.533**
46000	66,240,000	8.16	1.04	**.580**
48000	69,020,000	8.51	1.12	**.627**
50000	72,000,000	8.87	1.22	**.677**
52000	74,880,000	9.22	1.32	**.726**
54000	77,760,000	9.58	1.42	**.778**
56000	80,540,000	9.94	1.54	**.833**
58000	83,520,000	10.28	1.64	**.890**
60000	86,400,000	10.63	1.76	**.948**
62000	89,280,000	10.99	1.87	**1.070**
64000	92,160,000	11.34	2.00	**1.067**
66000	95,040,000	11.70	2.12	**1.130**
68000	79,920,000	12.05	2.25	**1.193**
70000	100,800,000	12.41	2.39	**1.258**

54 in. inside dia

Discharge in U S gallons per min	Discharge in U S gallons per 24 hr	Velocity feet per sec	Velocity head in ft	Head loss in feet per 100 ft
4000	5,760,000	.55	.005	**.005**
8000	11,520,000	1.11	.019	**.012**
12000	17,280,000	1.67	.043	**.027**
16000	23,040,000	2.23	.077	**.046**
20000	28,800,000	2.80	.122	**.069**
22000	31,680,000	3.07	.146	**.083**
24000	34,560,000	3.35	.174	**.098**
26000	37,440,000	3.63	.205	**.113**
28000	40,320,000	3.92	.238	**.130**
30000	43,200,000	4.20	.274	**.148**
32000	46,080,000	4.48	.311	**.167**
34000	48,960,000	4.76	.353	**.186**
36000	51,840,000	5.05	.395	**.206**
38000	54,720,000	5.33	.440	**.227**
40000	57,600,000	5.62	.490	**.249**
42000	60,480,000	5.89	.539	**.272**
44000	63,360,000	6.16	.590	**.297**
46000	66,240,000	6.44	.642	**.323**
48000	69,020,000	6.72	.701	**.351**
50000	72,000,000	7.00	.760	**.380**
52000	74,880,000	7.27	.820	**.410**
54000	77,760,000	7.56	.889	**.441**
56000	80,540,000	7.84	.952	**.473**
58000	83,520,000	8.12	1.02	**.505**
60000	86,400,000	8.40	1.10	**.538**
62000	89,280,000	8.68	1.17	**.572**
64000	92,160,000	8.96	1.25	**.605**
66000	95,040,000	9.24	1.32	**.641**
68000	97,920,000	9.52	1.40	**.678**
70000	100,800,000	9.80	1.49	**.714**
72000	103,680,000	10.07	1.57	**.752**
74000	106,560,000	10.35	1.66	**.791**
76000	109,440,000	10.62	1.75	**.832**
79000	112,320,000	10.91	1.85	**.873**
80000	115,200,000	11.19	1.94	**.915**

Factor for correcting to other pipe sizes (48 in.)

Dia in	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
47	1.043	1.088	**1.108**
46	1.089	1.186	**1.130**
45	1.138	1.295	**1.369**
44	1.190	1.416	**1.527**

Factor for correcting to other pipe sizes (54 in.)

Dia in	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
53	1.038	1.078	**1.095**
52	1.078	1.163	**1.202**
51	1.121	1.257	**1.321**
50	1.166	1.360	**1.452**

Friction Losses In Pipe; C = 100 (For old pipe)

60 in. inside dia

Discharge in U S gallons per min	Discharge in U S gallons per 24 hr	Velocity feet per sec	Velocity head in ft	Head loss in feet per 100 ft
5000	7,200,000	.56	.005	.003
10000	14,400,000	1.12	.019	.011
15000	21,600,000	1.70	.045	.024
20000	28,800,000	2.26	.079	.042
25000	36,000,000	2.83	.124	.062
30000	43,200,000	3.40	.179	.088
32000	46,080,000	3.63	.205	.099
34000	48,960,000	3.86	.230	.111
36000	51,840,000	4.09	.259	.124
38000	54,720,000	4.32	.290	.137
40000	57,600,000	4.55	.320	.150
42000	60,480,000	4.78	.354	.164
44000	63,360,000	5.00	.387	.180
46000	66,240,000	5.22	.422	.196
48000	69,020,000	5.45	.460	.212
50000	72,000,000	5.68	.500	.229
52000	74,880,000	5.90	.540	.246
54000	77,760,000	6.12	.582	.263
56000	80,540,000	6.35	.626	.281
58000	83,520,000	6.58	.672	.299
60000	86,400,000	6.81	.720	.319
62000	89,280,000	7.03	.768	.339
64000	92,160,000	7.25	.819	.360
66000	95,040,000	7.49	.870	.381
68000	97,920,000	7.72	.925	.403
70000	100,800,000	7.95	.980	.425
72000	103,680,000	8.17	1.04	.447
74000	106,560,000	8.40	.10	.470
76000	109,440,000	8.62	1.15	.493
78000	112,320,000	8.86	1.22	.517
80000	115,200,000	9.06	1.28	.541
85000	122,400,000	9.64	1.44	.607
90000	129,600,000	10.20	1.61	.676
95000	136,800,000	10.78	1.80	.747
100000	144,000,000	11.36	2.00	.822

72 in. inside dia

Discharge in U S gallons per min	Discharge in U S gallons per 24 hr	Velocity feet per sec	Velocity head in ft	Head loss in feet per 100 ft
10000	14,400,000	.78	.009	.005
20000	28,800,000	1.57	.038	.017
25000	36,000,000	1.97	.060	.026
30000	43,200,000	2.36	.086	.036
35000	50,400,000	2.76	.118	.048
40000	57,600,000	3.16	.154	.062
45000	64,800,000	3.54	.194	.077
50000	72,000,000	3.94	.240	.094
52000	74,880,000	4.09	.259	.100
54000	77,760,000	4.25	.280	.107
56000	80,540,000	4.41	.302	.114
58000	83,520,000	4.57	.324	.122
60000	86,400,000	4.73	.347	.130
62000	89,280,000	4.88	.370	.138
64000	92,160,000	5.04	.384	.146
66000	95,040,000	5.20	.420	.155
68000	97,920,000	5.36	.447	.164
70000	100,800,000	5.51	.473	.174
72000	103,680,000	5.67	.499	.183
74000	106,560,000	5.83	.528	.193
76000	109,440,000	5.99	.558	.203
78000	112,320,000	6.15	.588	.214
80000	115,200,000	6.31	.620	.225
82000	118,080,000	6.46	.650	.235
84000	120,960,000	6.62	.680	.245
86000	123,840,000	6.78	.712	.256
88000	126,720,000	6.93	.746	.266
90000	129,600,000	7.09	.780	.277
95000	136,800,000	7.49	.870	.306
100000	144,000,000	7.88	.965	.336
105000	151,200,000	8.28	1.06	.367
110000	158,400,000	8.67	1.16	.401
115000	165,600,000	9.05	1.27	.436
120000	172,800,000	9.45	1.38	.473
125000	180,000,000	9.85	1.51	.512

Factor for correcting to other pipe sizes (60 in.)

Dia in	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
59	1.034	1.070	1.085
58	1.070	1.145	1.179
57	1.108	1.228	1.284
56	1.148	1.318	1.399

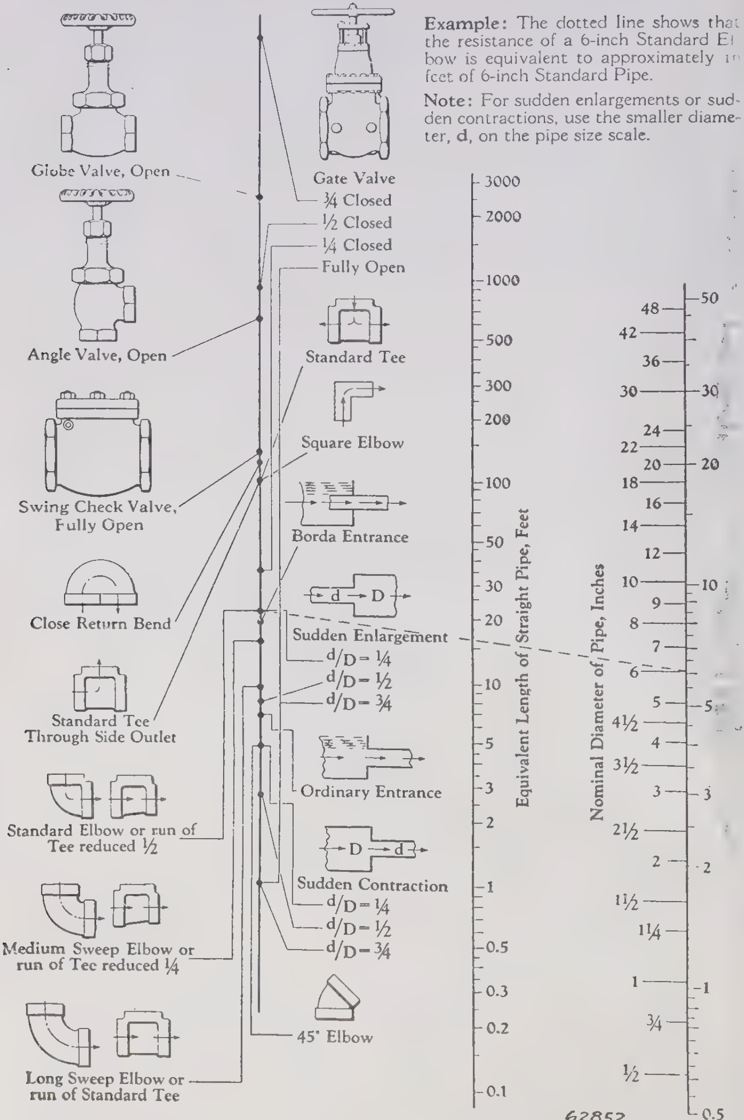
Factor for correcting to other pipe sizes (72 in.)

Dia in	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
70	1.058	1.119	1.147
68	1.121	1.257	1.318
66	1.190	1.416	1.527
64	1.266	1.602	1.774

Friction losses in pipe fittings

Example: The dotted line shows that the resistance of a 6-inch Standard El bow is equivalent to approximately in feet of 6-inch Standard Pipe.

Note: For sudden enlargements or sudden contractions, use the smaller diameter, **d**, on the pipe size scale.



This chart may be used for any liquid or g

Friction Loss in Pipe F[illegible] [illegible]ms of equiv[illegible] [illegible]et of straight pipe.

These data may be applied to any liquid or gas

Nominal pipe Size D_N Std. Wt.	Actual inside diam. in.	Gate Valve FULL OPEN	45° Elbow	Long-sweep elbow or run of Std tee	Std elbow or run of tee reduced ½	Std tee thru side outlet	Close return bend	Swing check valve FULL OPEN	Angle Valve FULL OPEN	Globe Valve FULL OPEN	Equivalent Resistance of Std. Wt. Welding Elbows Length of Straight Pipe (Feet)[1]* 90° Elbows Short Radius $R/D_N=1$	90° Elbows Long Radius $R/D_N=1½$	45° Elbows Short Radius $R/D_N=1$	45° Elbows Long Radius $R/D_N=1½$
Resistance factor		.19	.42	.6	.9	1.8	2.2	2.3	5.	10.				
½	.622	.35	.78	1.11	1.7	3.3	4.1	4.3	9.3	18.6	‡	0.68	‡	0.44
¾	.824	.44	.97	1.4	2.1	4.2	5.1	5.3	11.5	23.1	‡	0.91	‡	0.58
1	1.049	.56	1.23	1.8	2.6	5.3	6.5	6.8	14.7	29.4	1.6	1.15	1.01	0.74
1¼	1.380	.74	1.6	2.3	3.5	7.0	8.5	8.9	19.3	38.6	2.1	1.5	1.33	0.98
1½	1.610	.86	1.9	2.7	4.1	8.1	9.9	10.4	22.6	45.2	2.4	1.8	1.6	1.14
2	2.067	1.10	2.4	3.5	5.2	10.4	12.8	13.4	29	58	3.1	2.3	2.0	1.5
2½	2.469	1.32	2.9	4.2	6.2	12.4	15.2	15.9	35	69	3.7	2.7	2.4	1.7
3	3.068	1.6	3.6	5.2	7.7	15.5	18.9	19.8	43	86	4.7	3.4	3.0	2.2
4	4.026	2.1	4.7	6.8	10.2	20.3	24.8	26.0	57	113	6.1	4.4	3.9	2.9
5	5.047	2.7	5.9	8.5	12.7	25.4	31	33	71	142	7.7	5.6	4.9	3.6
6	6.065	3.2	7.1	10.2	15.3	31	37	39	85	170	9.2	6.7	5.9	4.3
7	7.024	3.7	8.3	11.8	17.7	35	43	45	98	197	‡‡	‡‡	‡‡	‡‡
8	7.981	4.3	9.4	13.4	20.2	40	49	52	112	224	12.1	8.8	7.7	5.7
10	10.020	5.3	11.8	16.9	25.3	51	62	65	141	281	15.2	11.0	9.7	7.1
12	12.000	6.4	14.1	20.2	30	61	74	77	168	336	18.2	13.2	11.6	8.5
14		7.5	16.5	23.5	35	71	86	90			20.1	14.6	12.8	9.4
16		8.5	18.8	26.9	40	81	99	104			23.1	16.8	14.7	10.8
18		9.6	21.2	30	45	91	111	116			26.2	19.0	16.7	12.2
20		10.7	23.5	34	50	101	123	129			29	21.2	18.6	13.6
24		12.8	28.2	40	61	121	148	155			35	25.6	22.5	16.5
30		16.0	35.3	50	76	151	185	193			44	32	28.3	20.7
36		19.2	42.4	61	91	181	222	232			53	39	34	25.0
42		22.4	49.4	71	106	212	259	271			63	45	40	29.2
48		25.6	57.6	81	121	242	296	310			72	52	46	33

Data on fittings based on information published by Crane Co.
*For 180° bend multiply values for 90° bend by 1.34.
[1]Data are based on Fanning coefficient of 0.006, as taken from Chart No. 18 of Catalog 211 of Tube Turns, Inc.
‡Short Radius elbows, $R/D_N=1$, not made in this size and weight.
‡‡Not made in this size.

Friction Losses through Miscellaneous Fittings

The friction losses below are given for use in making *approximate* estimates of friction loss through fittings not covered elsewhere in this book. They are based on the formula

$$h = k\frac{v^2}{2g} = .0155(k)(v^2)$$

in which; h = head loss due to fitting in ft (this is loss in addition to that in a straight pipe the length of the fitting)

k = Constant for type of fitting

v = velocity in pipe in ft per sec

g = acceleration due to gravity = about 32.2 ft per sec.

Type of fitting	k*
Square elbow (intersection of 2 cylinders at 90°)...	1.25
Square return elbow (180°)..........	2.5
Angle elbow (intersection of 2 cylinders at an angle other than 90°)..........	1.25 (angle/90°)^2
Disk or wobble-disk meter..........	3.4 to 10
Rotary meter (star or cog-wheel piston)..........	10
Reciprocating piston meter..........	15
Turbine wheel (double-flow, balanced) meter......	5 to 7.5
Horizontal (lift) check valve..........	8 to 12
Ball check valve..........	65 to 70

Elbows or bends made up of short sections of straight pipe welded together or circular bends with corrugated inner radius will have a friction loss from 1.3 to 1.6 times that of an equivalent smooth elbow or bend

*Values of k based on those in Hydraulics by Schoder and Dawson. and the Standards of the Hydraulic Institute.

2

Entrance Losses for Pipe in feet of liquid

These data apply to any liquid

Type of entrance	Value of k	Velocity in Feet Per Second (v)							
		2	3	4	5	6	7	8	9
Inward projecting pipe	.78	.05	.11	.19	.30	.44	.59	.78	.98
Sharp cornered	.50	.03	.07	.12	.19	.28	.38	.50	.63
Slightly rounded	.23	.01	.03	.06	.09	.13	.18	.23	.29
Bell mouthed	.04	.00	.01	.01	.02	.02	.03	.04	.05

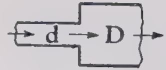
Type of entrance	Value of k	Velocity in Feet per Second (v)							
		10	12	15	20	25	30	35	40
Inward projecting pipe	.78	1.21	1.75	2.73	4.85	7.58	10.91	14.82	19.41
Sharp cornered	.50	.78	1.12	1.75	3.11	4.86	7.00	9.50	12.44
Slightly rounded	.23	.36	.51	.81	1.43	2.24	3.22	4.37	5.72
Bell mouthed	.04	.06	.09	.14	.25	.39	.56	.76	1.00

Courtesy of George B. Gascoigne, Consulting Engineer.

Based on Formula: $h = k \frac{v^2}{2g}$

In which
- h = entrance loss in feet of liquid.
- k = constant depending on shape of entrance.
- v = velocity of flow in feet per second.
- g = acceleration of gravity: at 45° latitude and sea level. g = 32.174 ft. per sec. per sec.

Loss of Head in Feet of Liquid Due to Sudden Enlargements



These data apply to any liquid

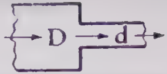
D/d	Velocity in smaller pipe in Feet Per Second												
	2	3	4	5	6	7	8	10	12	15	20	25	30	40
1.2	.01	.01	.02	.04	.06	.07	.10	.14	.21	.32	.55	.87	1.20	2.08
1.4	.02	.04	.06	.10	.14	.18	.23	.36	.51	.78	1.36	2.09	2.96	5.14
1.6	.02	.05	.09	.14	.20	.28	.36	.55	.78	1.19	2.07	3.16	4.50	7.82
1.8	.03	.07	.12	.18	.26	.35	.45	.70	.99	1.52	2.64	4.03	5.74	9.97
2.0	.04	.08	.14	.22	.31	.41	.53	.81	1.16	1.77	3.08	4.76	6.71	11.65
2.5	.05	.10	.17	.27	.38	.51	.66	1.01	1.44	2.20	3.83	5.93	8.34	14.48
3.0	.05	.11	.19	.30	.42	.57	.74	1.13	1.60	2.46	4.27	6.61	9.29	16.14
4.0	.06	.12	.22	.33	.47	.63	.82	1.25	1.78	2.76	4.73	7.29	10.30	17.90
5.0	.06	.13	.23	.35	.49	.66	.85	1.31	1.86	2.85	4.95	7.63	10.79	18.73
10.0	.06	.14	.24	.37	.52	.70	.91	1.39	1.97	2.96	5.25	8.07	11.44	19.87
8.	.06	.14	.24	.37	.53	.71	.92	1.42	2.01	3.09	5.36	8.21	11.66	20.26

D=Diameter Large Pipe.
d=Diameter Small Pipe.

Courtesy, George B. Gascoigne, Consulting Engineer.

Loss of Head in Feet of Liquid Due to Sudden Contractions

These data apply to any liquid



D/d	Velocity in Smaller Pipe in Feet Per Second												
	2	3	4	5	6	7	8	10	12	15	20	30	40
1.1	.00	.00	.01	.01	.02	.03	.04	.06	.09	.15	.29	.75	1.49
1.2	.00	.01	.02	.03	.04	.06	.07	.12	.18	.28	.54	1.38	2.74
1 4	.01	.02	.04	.07	.10	.13	.17	.27	.40	.65	1.14	2.68	4.98
1.6	.02	.04	.06	.10	.14	.20	.26	.40	.67	.89	1.56	3.44	5.97
1.8	.02	.05	.08	.13	.19	.25	.33	.51	.73	1.12	1.92	4.05	6.72
2.0	.02	.05	.09	.14	.21	.28	.36	.55	.79	1.19	2.06	4.28	7.09
2.2	.02	.06	.10	.15	.22	.30	.38	.59	.84	1.28	2.20	4.56	7.41
2.5	.03	.06	.10	.16	.23	.31	.40	.62	.88	1.34	2.30	4.76	7.71
3.0	.03	.06	.11	.17	.24	.32	.42	.65	.92	1.40	2.41	4.98	8.11
4.0	.03	.06	.12	.18	.25	.34	.44	.69	.97	1.48	2.53	5.24	8.48
5.0	.03	.07	.12	.18	.26	.35	.46	.70	1.00	1.52	2.60	5.36	8.67
10.0	.03	.07	.12	.19	.27	.36	.47	.72	1.02	1.56	2.68	5.56	9.06
8.	.03	.07	.12	.19	.27	.36	.47	.72	1.03	1.58	2.71	5.68	9.36

D = Diameter of Larger Pipe.
d = Diameter of Smaller Pipe.

Courtesy of George B. Gascoigne, Consulting Engineer

Loss of Head in Feet of Liquid due to Partially Closed Valves or other Obstructions

These data apply to any liquid

$\frac{A}{A°}$	Velocity in Pipe in Feet Per Second 1	2	3	4	5	6	7	8	10	12	15	20	30
1.05	.00	.01	.01	.03	.04	.06	.08	.10	.15	.23	.36	.61	1.37
1.1	.00	.01	.03	.05	.07	.11	.15	.19	.30	.43	.67	1.20	2.70
1.2	.01	.03	.06	.10	.16	.24	.32	.42	.65	.94	1.47	2.61	5.88
1.4	.01	.06	.13	.24	.37	.54	.73	.95	1.49	2.14	3.35	5.95	13.35
1.6	.02	.10	.22	.38	.60	.86	1.17	1.53	2.39	3.44	5.38	9.56	21.52
1.8	.03	.13	.30	.54	.84	1.22	1.66	2.16	3.38	4.87	7.64	13.21	30.42
2.0	.04	.17	.38	.67	1.05	1.51	2.06	2.69	4.20	6.05	9.46	16.82	37.84
2.2	.05	.20	.46	.81	1.27	1.83	2.49	3.26	5.09	7.33	11.45	20.35	45.78
2.5	.06	.25	.56	1.00	1.56	2.24	3.05	3.98	6.23	8.97	14.01	24.91	56.05
3.0	.08	.31	.71	1.26	1.97	2.83	3.85	5.03	7.87	11.33	17.70	31.47	70.80
4.0	.10	.42	.94	1.68	2.62	3.78	5.14	6.71	10.49	15.10	23.60	41.95	94.40
5.0	.12	.50	1.12	1.99	3.11	4.48	6.10	7.97	12.46	17.94	28.02	49.82	112.1
6.0	.15	.58	1.31	2.33	3.64	5.25	7.14	9.33	14.58	20.99	32.79	58.30	131.2
7.0	.16	.65	1.46	2.59	4.05	5.83	7.93	10.36	16.19	23.31	36.41	64.74	145.7
8.0	.18	.70	1.59	2.82	4.41	6.35	8.64	11.28	17.63	25.39	39.66	70.51	158.7
9.0	.19	.78	1.74	3.10	4.84	6.97	9.49	12.39	19.37	27.89	43.57	77.47	174.3
10.0	.21	.84	1.89	3.36	5.26	7.57	10.30	13.45	21.02	30.27	47.30	84.09	189.2

A = Area of Pipe.
A° = Area of Opening.
Courtesy of George B. Gascoigne, Consulting Engineer.

Friction Losses in Copper and Brass Tubing and Pipe; for Water

Copper and brass tubing and pipe is made in standard sizes having different inside diameters than steel or cast-iron pipe, and the inside finish is usually better. To avoid the use of interpolation and correction factors to the tables for cast-iron and steel pipe, a special set of tables is given on the following pages.

These tables are based on the Williams and Hazen formula which appears on page 27. They are calculated using a value of C = 130, which expresses the average inside surface conditions of copper and brass pipe and tubing. Experiments show that under ideal conditions somewhat less friction will be encountered. For very smooth, new pipe a constant C = 140 may, therefore, be used. These tables can be corrected to this constant by multiplying the head loss shown by the factor .87.

It will be noted that this formula furnishes values in close coincidence with those obtained by the formula proposed by Saph and Schoder on the basis of their experiments with small pipe. It reads

$$f = .1381 \frac{q^{1.75}}{d^{4.75}}$$

in which f = friction loss in ft of liquid per 100 ft of pipe
d = inside diameter of pipe in inches
q = flow in gal per min

The remarks made on page 27 regarding viscosity and temperature limitations also apply to these tables.

⅜ Inch

Flow — US gal per min	Type K Tubing .402″ Inside Dia .049″ Wall Thk		Type L Tubing .430″ Inside Dia .035″ Wall Thk		Type M Tubing .450″ Inside Dia .025″ Wall Thk		Pipe .494″ Inside Dia .0905″ Wall Thk		Flow — US gal per min
	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	
¼	.63	.838	.551	.595	.503	.479	.419	.306	¼
½	1.26	3.03	1.10	2.15	1.005	1.72	.836	1.10	½
¾	1.89	6.41	1.65	4.56	1.51	3.65	1.26	2.33	¾
1	2.52	10.9	2.20	7.75	2.01	6.22	1.68	3.98	1
1½	3.78	23.0	3.30	16.4	3.02	13.15	2.51	8.42	1½
2	5.04	39.3	4.40	28.0	4.02	22.4	3.35	14.4	2
2½	6.30	59.5	5.50	42.3	5.03	33.9	4.19	21.7	2½
3	7.55	83.1	6.60	59.1	6.04	47.6	5.02	30.4	3
3½	8.82	110.8	7.70	79.0	7.04	63.5	5.86	40.6	3½
4	10.1	141.7	8.80	101.	8.05	80.9	6.70	51.8	4
4½	11.4	176.	9.90	126.	9.05	100.	7.53	64.1	4½
5	12.6	214.	11.0	152.	10.05	122.	8.36	78.0	5

Friction Losses in Copper and Brass Tubing and Pipe; C=130

½ Inch

Flow — U S gal per min	Type K Tubing .527″ Inside Dia .049″ Wall Thk		Type L Tubing .545″ Inside Dia .040″ Wall Thk		Type M Tubing .569″ Inside Dia .028″ Wall Thk		Pipe .625″ Inside Dia .1075″ Wall Thk		Flow — U S gal per min
	Velocity ft /sec	Head Loss ft /100 ft	Velocity ft /sec	Head Loss ft /100 ft	Velocity ft /sec	Head Loss ft /100 ft	Velocity ft /sec	Head Loss ft /100 ft	
½	.735	.804	.687	.681	.631	.554	.522	.35	½
1	1.47	2.90	1.375	2.46	1.26	2.00	1.04	1.26	1
1½	2.20	6.29	2.06	5.26	1.90	4 28	1.57	2.67	1½
2	2.94	10.5	2.75	8.89	2.53	7.22	2.09	4.56	2
2½	3.67	15.8	3.44	13.4	3.16	10.9	2.61	6.88	2½
3	4.40	22.2	4.12	18.8	3.79	15.3	3.13	9.66	3
3½	5.14	29.5	4.81	25.1	4.42	20.4	3.66	12.9	3½
4	5.87	37.7	5.50	32.0	5.05	26.0	4.18	16.4	4
4½	6 61	46.8	6.19	39.6	5.68	32.1	4.70	20.4	4½
5	7.35	56.9	6.87	48.2	6.31	39.2	5.22	24.8	5
6	8.81	79.7	8.25	67.7	7.59	55.0	6.26	34.8	6
7	10.3	106.	9.62	89.8	8.84	73.2	7.31	46.1	7
8	11.8	136.	11.0	116.	10.1	93.7	8 35	59.4	8
9	13.2	169.	12.4	143.	11.4	117.	9.40	73.5	9
10	14.7	205.	13.8	174.	12.6	142.	10.4	89.4	10

⅝ Inch

Flow — U S gal per min	Type K Tubing .652″ Inside Dia .049″ Wall Thk		Type L Tubing .666″ Inside Dia .042″ Wall Thk		Type M Tubing .690″ Inside Dia .030″ Wall Thk		Pipe		Flow — U S gal per min
	Velocity ft /sec	Head Loss ft /100 ft	Velocity ft./sec.	Head Loss ft /100 ft	Velocity ft /sec	Head Loss ft /100 ft			
½	.480	.285	.459	.256	.429	.218			½
1	.960	1.03	.918	.925	.857	.785			1
1½	1.44	2.18	1.38	1.96	1.29	1.66			1½
2	1.92	3.72	1.84	3.34	1.72	2.84			2
2½	2.40	5.61	2.30	5.03	2.14	4.28			2½
3	2.88	7.88	2.75	7.09	2.57	6.01			3
3½	3.36	10.5	3.21	9.45	3.00	7.97			3½
4	3.84	13.4	3.67	12.0	3.43	10.2			4
4½	4.32	16.6	4.13	14.9	3.86	12.7			4½
5	4.80	20.2	4.59	18.2	4.29	15.4			5
6	5.75	28.3	5.51	25.5	5.15	21.6			6
7	6.71	37.6	6.42	33.8	6.00	28.7			7
8	7.67	48.2	7.35	43.5	6.85	36.9			8
9	8.64	60.0	8.25	53.9	7.71	45.7			9
10	9.60	73.1	9.18	65.6	8.57	55.8			10
11	10.6	87.0	10.1	78.1	9.43	66.1			11
12	11.5	102.	11.0	91.7	10.3	77.8			12
13	12.5	119.	11.9	107.	11.2	90.4			13

2

Friction Losses in Copper and Brass Tubing and Pipe; C=130

¾ Inch

Flow — US gal per min	Type K Tubing .745″ Inside Dia .065″ Wall Thk		Type L Tubing .785″ Inside Dia .045″ Wall Thk		Type M Tubing .811″ Inside Dia .032″ Wall Thk		Pipe .822″ Inside Dia .114″ Wall Thk		Flow — US gal per min
	Velocity ft/sec	Head Loss ft/100 ft.	Velocity ft/sec	Head Loss ft/100 ft	Velocity ft/sec	Head Loss ft/100 ft	Velocity ft/sec	Head Loss ft/100 ft	
1	.735	.535	.662	.416	.62	.354	.604	.335	1
2	1.47	1.93	1.33	1.50	1.24	1.28	1.21	1.21	2
3	2.21	4.09	1.99	3.18	1.86	2.71	1.81	2.56	3
4	2.94	6.95	2.65	5.40	2.48	4.60	2.42	4.36	4
5	3.67	10.5	3.31	8.15	3.10	6.94	3.02	6.57	5
6	4.41	14.7	3.98	11.5	3.72	9.75	3.62	9.22	6
7	5.14	19.6	4.64	15.2	4.34	12.9	4.23	12.2	7
8	5.88	25.2	5.30	19.5	4.96	16.6	4.83	15.7	8
9	6.61	31.2	5.96	24.2	5.59	20.6	5.44	19.5	9
10	7.35	37.9	6.62	29.4	6.20	25.1	6.04	23.7	10
11	8.09	45.1	7.29	35.1	6.82	29.8	6.64	28.2	11
12	8.83	53.1	7.95	41.2	7.44	35.2	7.25	33.2	12
13	9.56	61.5	8.61	47.9	8.06	40.7	7.85	38.5	13
14	10.3	70.6	9.27	54.9	8.68	46.7	8.45	44.2	14
15	11.0	80.3	9.94	62.4	9.30	53.1	9.05	50.2	15
16	11.8	90.5	10.6	70.3	9.92	59.8	9.65	56.6	16
17	12.5	101.1	11.25	78.6	10.55	66.9	10.25	63.4	17
18	13.2	112.3	11.92	87.5	11.17	74.4	10.85	70.4	18

1 Inch

Flow — US gal per min	Type K Tubing .995″ Inside Dia .065″ Wall Thk		Type L Tubing 1.025″ Inside Dia .050″ Wall Thk		Type M Tubing 1.055″ Inside Dia .035″ Wall Thk		Pipe 1.062″ Inside Dia .1265″ Wall Thk		Flow — US gal per min
	Velocity ft/sec	Head Loss ft/100 ft	Velocity ft/sec	Head Loss ft/100 ft	Velocity ft/sec	Head Loss ft/100 ft	Velocity ft/sec	Head Loss ft/100 ft	
2	.824	.475	.778	.411	733	.358	.722	.345	2
3	1.24	1.01	1.17	.871	1.10	.758	1.08	.732	3
4	1.65	1.71	1.56	1.48	1.47	1.29	1.45	1.24	4
5	2.06	2.58	1.95	2.23	1.83	1.94	1.81	1.88	5
6	2.48	3.62	2.34	3.13	2.20	2.72	2.17	2.63	6
7	2.89	4.80	2.72	4.15	2.56	3.62	2.53	3.49	7
8	3.30	6.18	3.11	5.35	2.93	4.65	2.89	4.50	8
9	3.71	7.65	3.50	6.63	3.30	5.76	3.25	5.56	9
10	4.12	9.34	3.89	8.08	3.66	7.02	3.61	6.77	10
12	4.95	13.0	4.67	11.3	4.40	9.83	4.34	9.47	12
14	5.77	17.4	5.45	15.0	5.13	13.1	5.05	12.6	14
16	6.60	22.2	6.22	19.2	5.86	16.8	5.78	16.2	16
18	7.42	27.6	7.00	23.9	6.60	20.8	6.50	20.1	18
20	8.24	33.5	7.78	29.0	7.33	25.1	7.22	24.4	20
25	10.30	50.6	9.74	43.9	9.16	38.2	9.03	36.8	25
30	12.37	71.0	11.68	61.4	11.00	53.4	10.84	51.6	30
35	14.42	94.5	13.61	81.8	12.82	71.2	12.65	68.7	35
40	16.50	121.	15.55	105.	14.66	91.1	14.45	88.0	40
45	18.55	151.	17.50	130.	16.50	113.	16.25	109.	45
50	20.60	183.	19.45	158.	18.32	138.	18.05	133.	50

Friction Losses in Copper and Brass Tubing and Pipe; C=130

1¼ Inch

Flow — US Gal Per Min	Type K Tubing 1.245" Inside Dia. .065" Wall Thk. Velocity ft./sec.	Head Loss ft./100 ft.	Type L Tubing 1.265" Inside Dia. .055" Wall Thk. Velocity ft./sec.	Head Loss ft./100 ft.	Type M Tubing 1.291" Inside Dia. .042" Wall Thk. Velocity ft./sec.	Head Loss ft./100 ft.	Pipe 1.368" Inside Dia. .146" Wall Thk. Velocity ft./sec.	Head Loss ft./100 ft.	Flow — US Gal Per Min
5	1.315	.862	1.28	.800	1.22	.725	1.093	.545	5
6	1.58	1.21	1.53	1.12	1.47	1.02	1.31	.765	6
7	1.84	1.61	1.79	1.49	1.71	1.35	1.53	1.02	7
8	2.11	2.07	2.04	1.92	1.96	1.74	1.75	1.31	8
9	2.37	2.56	2.30	2.38	2.20	2.15	1.96	1.62	9
10	2.63	3.12	2.55	2.90	2.45	2.62	2.18	1.98	10
12	3.16	4.37	3.06	4.04	2.93	3.66	2.62	2.75	12
15	3.95	6.60	3.83	6.12	3.66	5.55	3.27	4.17	15
20	5.26	11.2	5.10	10.4	4.89	9.44	4.36	7.10	20
25	6.58	17.0	6.38	15.7	6.11	14.3	5.46	10.7	25
30	7.90	23.7	7.65	22.1	7.33	19.9	6.55	15.0	30
35	9.21	31.6	8.94	29.3	8.55	26.6	7.65	20.0	35
40	10.5	40.5	10.2	37.6	9.77	34.0	8.74	25.6	40
45	11.8	50.4	11.5	46.7	11.0	42.4	9.83	31.8	45
50	13.2	61.1	12.8	56.7	12.2	51.4	10.9	38.7	50
60	15.8	85.7	15.3	79.5	14.7	72.1	13.1	54.1	60
70	18.4	114.	17.9	106.	17.1	96.0	15.3	72.2	70
80	21.1	146.	20.4	136.	19.6	123.	17.5	92.4	80
90	23.7	182.	23.0	168.	22.0	153.	19.6	115.	90
100	26.3	221.	25.5	204.	24.4	186.	21.8	140.	100

1½ Inch

Flow — US Gal Per Min	Type K Tubing 1.481" Inside Dia. .072" Wall Thk. Velocity ft./sec.	Head Loss ft./100 ft.	Type L Tubing 1.505" Inside Dia. .060" Wall Thk. Velocity ft./sec.	Head Loss ft./100 ft.	Type M Tubing 1.527" Inside Dia. .049" Wall Thk. Velocity ft./sec.	Head Loss ft./100 ft.	Pipe 1.600" Inside Dia. .150" Wall Thk. Velocity ft./sec.	Head Loss ft./100 ft.	Flow — US Gal Per Min
8	1.49	.885	1.44	.822	1.40	.768	1.275	.611	8
9	1.67	1.10	1.62	1.02	1.57	.951	1.435	.757	9
10	1.86	1.34	1.80	1.24	1.75	1.16	1.59	.923	10
12	2.23	1.87	2.16	1.73	2.10	1.62	1.91	1.29	12
15	2.79	2.84	2.70	2.62	2.63	2.45	2.39	1.95	15
20	3.72	4.82	3.60	4.46	3.50	4.16	3.19	3.31	20
25	4.65	7.28	4.51	6.74	4.38	6.29	3.98	5.00	25
30	5.58	10.2	5.41	9.44	5.25	8.80	4.78	7.00	30
35	6.51	13.6	6.31	12.6	6.13	11.8	5.58	9.35	35
40	7.44	17.4	7.21	16.1	7.00	15.0	6.37	12.0	40
45	8.37	21.6	8.11	20.0	7.88	18.7	7.16	14.9	45
50	9.30	26.3	9.01	24.3	8.76	22.7	7.96	18.1	50
60	11.2	36.8	10.8	34.1	10.5	31.8	9.56	25.3	60
70	13.0	49.1	12.6	45.5	12.3	42.4	11.2	33.8	70
80	14.9	62.8	14.4	58.1	14.0	54.2	12.8	43.1	80
90	16.7	78.0	16.2	72.1	15.8	67.3	14.4	53.6	90
100	18.6	94.8	18.0	87.7	17.5	82.0	15.9	65.1	100
110	20.5	113.	19.8	104.5	19.3	97.5	17.5	77.8	110
120	22.3	133.	21.6	123.	21.0	115.	19.1	91.2	120
130	24.2	154.	23.4	143.	22.8	133.	20.7	106.	130

Friction Losses in Copper and Brass Tubing and Pipe; C=130

2 Inch

Flow — US Gal Per Min	Type K Tubing 1.959" Inside Dia. .083" Wall Thk. Velocity ft./sec.	Type K Tubing Head Loss ft./100ft.	Type L Tubing 1.985" Inside Dia. .070" Wall Thk. Velocity ft./sec.	Type L Tubing Head Loss ft./100ft.	Type M Tubing 2.009" Inside Dia. .058" Wall Thk. Velocity ft./sec.	Type M Tubing Head Loss ft./100ft.	Pipe 2.062" Inside Dia. .1565" Wall Thk. Velocity ft./sec.	Pipe Head Loss ft./100ft.	Flow — US Gal Per Min
10	1.07	.845	1.04	.321	1.01	.306	.957	.268	10
12	1.28	.481	1.24	.450	1.21	.426	1.15	.373	12
14	1.49	.641	1.45	.598	1.42	.569	1.34	.497	14
16	1.70	.821	1.66	.767	1.62	.732	1.53	.641	16
18	1.92	1.02	1.87	.953	1.82	.905	1.72	.792	18
20	2.13	1.24	2.07	1.16	2.02	1.10	1.92	.962	20
25	2.66	1.87	2.59	1.75	2.53	1.66	2.39	1.45	25
30	3.19	2.62	3.11	2.45	3.03	2.32	2.87	2.03	30
35	3.73	3.50	3.62	3.26	3.54	3.10	3.35	2.71	35
40	4.26	4.48	4.14	4.18	4.05	3.96	3.83	3.47	40
45	4.79	5.56	4.66	5.20	4.55	4.94	4.30	4.31	45
50	5.32	6.76	5.17	6.32	5.05	5.99	4.80	5.24	50
60	6.39	9.47	6.21	8.85	6.06	8.40	5.75	7.34	60
70	7.45	12.6	7.25	11.8	7.07	11.2	6.70	9.78	70
80	8.52	16.2	8.28	15.1	8.09	14.3	7.65	12.5	80
90	9.58	20.0	9.31	18.7	9.10	17.8	8.61	15.6	90
100	10.65	24.4	10.4	22.7	10.1	21.6	9.57	18.9	100
110	11.71	29.0	11.4	27.2	11.1	25.8	10.5	22.5	110
120	12.78	34.1	12.4	31.8	12.1	30.4	11.5	26.6	120
130	13.85	39.6	13.4	36.9	13.1	35.1	12.5	30.7	130
140	14.9	45.5	14.5	42.3	14.2	40.3	13.4	35.2	140
150	16.0	51.6	15.5	48.1	15.2	45.8	14.4	40.1	150
160	17.0	58.1	16.5	54.2	16.2	51.5	15.3	45.1	160
170	18.1	65.1	17.6	60.6	17.2	57.7	16.3	50.5	170
180	19.2	72.4	18.6	67.4	18.2	64.1	17.2	56.1	180
190	20.2	79.9	19.6	74.3	19.2	70.7	18.2	62.0	190
200	21.3	87.8	20.7	81.9	20.2	77.9	19.2	68.0	200
210	22.4	96.5	21.7	89.6	21.2	85.5	20.1	74.5	210
220	23.4	105.	22.8	97.5	22.2	93.1	21.0	81.0	220
230	24.5	114.	23.8	106.	23.2	101.	22.0	88.2	230
240	25.6	124.	24.8	115.	24.3	110.	23.0	95.6	240
250	26.6	133.	25.9	124.	25.3	118.	23.9	103.	250
260	27.7	143.	26.9	133.	26.3	127.	24.9	111.	260
270	28.8	153.	27.9	143.	27.3	136.	25.8	119.	270
280	29.8	164.	29.0	153.	28.3	145.	26.8	127.	280
290	30.9	174.	30.0	163.	29.4	154.	27.8	135.	290
300	32.0	186.	31.1	174.	30.4	165.	28.7	144.	300

Friction Losses in Copper and Brass Tubing and Pipe; C=130

2½ Inch

Flow — US Gal Per Min	Type K Tubing 2.435" Inside Dia. .095" Wall Thk.		Type L Tubing 2.465" Inside Dia. .080" Wall Thk.		Type M Tubing 2.495" Inside Dia. .065" Wall Thk.		Pipe 2.500" Inside Dia. .1875" Wall Thk.		Flow — US Gal Per Min
	Velocity ft./sec.	Head Loss ft./100 ft.	Velocity ft./sec.	Head Loss ft./100 ft.	Velocity ft./sec.	Head Loss ft./100 ft.	Velocity ft./sec.	Head Loss ft./100 ft.	
20	1.38	.429	1.34	.404	1.31	.381	1.31	.375	20
25	1.72	.649	1.68	.609	1.64	.575	1.63	.565	25
30	2.07	.910	2.02	.852	1.97	.805	1.96	.792	30
35	2.41	1.21	2.35	1.14	2.30	1.07	2.29	1.06	35
40	2.76	1.55	2.69	1.46	2.62	1.37	2.61	1.35	40
45	3.10	1.93	3.02	1.81	2.95	1.71	2.94	1.68	45
50	3.45	2.34	3.36	2.20	3.28	2.07	3.26	2.04	50
60	4.14	3.28	4.03	3.08	3.93	2.91	3.92	2.86	60
70	4.82	4.36	4.70	4.11	4.59	3.88	4.57	3.82	70
80	5.51	5.58	5.37	5.25	5.25	4.96	5.22	4.88	80
90	6.20	6.95	6.04	6.52	5.90	6.15	5.88	6.06	90
100	6.89	8.43	6.71	7.94	6.55	7.48	6.53	7.37	100
110	7.58	10.1	7.38	9.44	7.21	8.90	7.19	8.8	110
120	8.27	11.8	8.05	11.1	7.86	10.5	7.84	10.3	120
130	8.96	13.7	8.73	12.9	8.52	12.1	8.49	12.0	130
140	9.65	15.7	9.40	14.8	9.18	13.9	9.14	13.7	140
150	10.35	17.9	10.1	16.8	9.83	15.8	9.79	15.6	150
160	11.0	20.1	10.8	18.9	10.5	17.8	10.45	17.6	160
170	11.7	22.5	11.4	21.1	11.1	20.0	11.1	19.7	170
180	12.4	25.0	12.1	23.6	11.8	22.2	11.8	21.9	180
190	13.1	27.6	12 8	26.0	12.5	24.5	12.4	24.2	190
200	13.8	30.4	13.4	28.6	13.1	27.0	13.1	26.6	200
220	15.2	36.2	14.8	34.2	14.4	32.2	14.4	31.8	220
240	16.5	42.6	16.1	40.2	15.7	37.9	15.7	37.4	240
260	17.9	49.3	17.5	46.5	17.1	43.9	17.0	43.3	260
280	19.3	56.7	18.8	53.2	18.4	50.2	18.3	49.4	280
300	20.7	64.5	20.1	61.1	19.7	57.6	19.6	56.8	300
320	22.1	72.6	21.5	68.6	21.0	64.7	20.9	63.8	320
340	23.4	81.2	22.8	76.3	22.3	72.0	22.2	70.9	340
360	24.8	90.3	24.2	84.9	23.6	80.0	23.5	78.9	360
380	26.2	99.7	25.5	93.7	24.9	88.5	24.8	87.0	380
400	27.6	109.	26.9	103.	26.2	97.0	26.1	95.6	400
420	29.0	120.	28.2	113.	27.5	106.	27.4	105.	420
440	30.3	131.	29.5	122.	28.8	116.	28.7	114.	440
460	31.7	142.	30.9	133.	30.2	126.	30.0	124.	460
480	33.1	154.	32.2	144.	31.5	136.	31.4	134.	480
500	34.5	166.	33.6	155.	32.8	147.	32.6	145.	500

Friction Losses in Copper and Brass Tubing and Pipe; C=130

3 Inch

Flow — U S Gal Per Min	Type K Tubing 2.907" Inside Dia. .109" Wall Thk.		Type L Tubing 2.945" Inside Dia. .090" Wall Thk.		Type M Tubing 2.981" Inside Dia. .072" Wall Thk.		Pipe 3.062" Inside Dia. .219" Wall Thk.		Flow — U S Gal Per Min
	Velocity ft./sec.	Head Loss ft./100 ft.	Velocity ft./sec.	Head Loss ft./100 ft.	Velocity ft./sec.	Head Loss ft./100 ft.	Velocity ft./sec.	Head Loss ft./100 ft.	
20	.964	.182	.940	.171	.916	.161	.87	.141	20
30	1.45	.385	1.41	.361	1.37	.341	1.30	.299	30
40	1.93	.656	1.88	.616	1.83	.580	1.74	.509	40
50	2.41	.992	2.35	.931	2.29	.878	2.17	.770	50
60	2.89	1.39	2.82	1.31	2.75	1.23	2.61	1.08	60
70	3.38	1.85	3.29	1.73	3.20	1.64	3.04	1.43	70
80	3.86	2.37	3.76	2.22	3.66	2.09	3.48	1.84	80
90	4.34	2.94	4.23	2.76	4.12	2.60	3.91	2.28	90
100	4.82	3.57	4.70	3.35	4.59	3.16	4.35	2.77	100
110	5.30	4.26	5.17	4.00	5.05	3.77	4.79	3.31	110
120	5.79	5.01	5.64	4.70	5.50	4.43	5.21	3.89	120
130	6.27	5.81	6.11	5.44	5.95	5.14	5.65	4.50	130
140	6.75	6.66	6.58	6.25	6.41	5.89	6.09	5.16	140
150	7.24	7.56	7.05	7.10	6.87	6.70	6.52	5.88	150
160	7.72	8.52	7.52	8.00	7.34	7.55	6.95	6.62	160
170	8.20	9.52	7.99	8.94	7.79	8.43	7.39	7.40	170
180	8.69	10.6	8.46	9.94	8.25	9.37	7.82	8.22	180
190	9.16	11.7	8.93	11.0	8.70	10.4	8.25	9.08	190
200	9.64	12.9	9.40	12.1	9.16	11.4	8.70	10.0	200
220	10.6	15.3	10.3	14.4	10.1	13.6	9.56	11.9	220
240	11.6	18.1	11.3	16.9	11.0	16.0	10.4	14.0	240
260	12.6	20.9	12.2	19.6	11.9	18.5	11.3	16.2	260
280	13.5	24.0	13.2	22.6	12.8	21.3	12.2	18.7	280
300	14.5	27.3	14.1	25.6	13.7	24.2	13.0	21.2	300
320	15.4	30.7	15.0	28.8	14.7	27.2	13.9	23.9	320
340	16.4	34.4	16.0	32.2	15.6	30.4	14.8	26.7	340
360	17.4	38.2	16.9	35.9	16.5	33.8	15.7	29.7	360
380	18.3	42.2	17.9	39.6	17.4	37.4	16.5	32.8	380
400	19.3	46.4	18.8	43.6	18.3	41.2	17.4	36.0	400
450	21.7	57.9	21.2	54.2	20.6	51.2	19.6	44.8	450
500	24.1	70.2	23.5	65.8	22.9	62.1	21.7	54.4	500
550	26.6	83.8	25.8	78.5	25.2	74.1	23.9	65.1	550
600	29.0	98.4	28.2	92.3	27.5	87.0	26.1	76.4	600
650	31.4	114.	30.6	107.	29.8	101.	28.2	88.6	650
700	33.8	131.	32.9	123.	32.1	116.	30.4	101.5	700
750	36.2	149.	35.2	140.	34.4	132.	32.6	115.	750
800	38.6	167.	37.6	157.	36.6	148.	34.8	130.	800

Friction Losses in Copper and Brass Tubing and Pipe; C = 130

3½ Inch

Flow — US Gal Per Min	Type K Tubing 3.385" Inside Dia. .120" Wall Thk.		Type L Tubing 3.425" Inside Dia. .100" Wall Thk.		Type M Tubing 3.459" Inside Dia. .083" Wall Thk.		Pipe 3.500" Inside Dia. .250" Wall Thk.		Flow — US Gal Per Min
	Velocity ft./sec.	Head Loss ft./100ft	Velocity ft./sec.	Head Loss ft./100ft.	Velocity ft./sec.	Head Loss ft /100ft.	Velocity ft./sec.	Head Loss ft./100ft.	
60	2.14	.666	2.09	.628	2.05	.596	2.00	.563	60
70	2.49	.889	2.44	.835	2.39	.793	2.33	.748	70
80	2.84	1.14	2.78	1.07	2.73	1.02	2.66	.957	80
90	3.20	1.41	3.13	1.33	3.07	1.26	3.00	1.19	90
100	3.56	1.72	3.48	1.61	3.41	1.53	3.33	1.45	100
110	3.92	2.04	3.82	1.93	3.76	1.83	3.67	1.73	110
120	4.26	2.41	4.18	2.26	4.10	2.15	4.00	2.03	120
130	4.62	2.78	4.52	2.62	4.45	2.49	4.33	2.35	130
140	4.98	3.20	4.87	3.01	4.79	2.86	4.66	2.70	140
150	5.34	3.63	5.21	3.42	5.12	3.24	5.00	3.07	150
160	5 69	4.09	5.56	3.85	5.46	3.66	5.33	3.46	160
170	6.05	4.59	5.91	4.31	5.80	4.08	5.66	3.87	170
180	6.40	5.09	6.26	4.78	6.16	4.55	6.00	4.30	180
190	6.76	5.62	6.60	5.28	6.49	5.02	6.33	4.74	190
200	7.11	6.18	6.95	5.81	6.82	5.52	6.66	5.22	200
220	7.82	7.40	7.65	6.93	7.51	6.58	7.33	6.22	220
240	8.54	8.70	8.35	8.14	8.19	7.74	8.00	7.32	240
260	9.25	10.1	9.05	9.44	8.87	8.97	8.66	8.47	260
280	9.95	11.5	9.74	10.8	9.55	10.3	9.33	9.74	280
300	10.7	13.1	10.4	12.3	10.2	11.7	10.0	11.1	300
350	12.5	17.4	12.2	16.4	11.9	15.6	11.7	14.7	350
400	14.2	22.2	13.9	21.0	13.7	19.9	13.3	18.9	400
450	16.0	27.7	15.6	26.1	15.4	24.8	15.0	23.4	450
500	17.8	33.6	17.4	31.7	17.1	30.1	16.7	28.4	500
550	19.6	40.1	19.1	37.8	18.8	36.0	18.3	34.0	550
600	21.4	47.2	20.9	44.4	20.5	42.2	20.0	29.9	600
650	23.1	54.7	22.6	51.5	22 2	48.9	21.6	46.3	650
700	24.9	62.8	24.4	59.1	23.9	56.2	23.3	53.0	700
750	26.6	71.5	26.1	67.2	25.6	63.8	25.0	60.3	750
800	28.4	80.5	27.8	75.6	27.3	71.8	26.6	67.8	800
850	30.2	90.4	29.6	84.6	29.0	80.5	28.3	75.9	850
900	32.0	100.	31.3	94.1	30.7	89.4	30.0	84.4	900
950	33.8	111.	33.0	104.	32.4	98.8	31.6	93.3	950
1000	35.6	122.	34.8	114.	34.1	109.	33.3	102.5	1000
1100	39.2	145.	38.2	136.	37.6	130.	36.7	123.	1100
1200	42.6	170.	41.8	160.	41.0	152.	40.0	144.	1200
1300	46.2	197.	45.2	186.	44.5	177.	43 3	167.	1300
1400	49.8	226.	48.7	213.	47.9	202.	46.6	191.	1400

The National Bureau of Standards has recommended the elimination of this pipe size.

Friction Losses in Copper and Brass Tubing and Pipe; C=130

4 Inch

Flow — US Gal Per Min	Type K Tubing 3.857" Inside Dia. .134" Wall Thk.		Type L Tubing 3.905" Inside Dia. .110" Wall Thk.		Type M Tubing 3.935" Inside Dia. .095" Wall Thk.		Pipe 4.000" Inside Dia. .250" Wall Thk.		Flow — US Gal Per Min
	Velocity ft./sec.	Head Loss ft./100ft.	Velocity ft./sec.	Head Loss ft./100ft.	Velocity ft./sec.	Head Loss ft./100ft.	Velocity ft./sec.	Head Loss ft./100ft.	
100	2.74	.898	2.68	.846	2.64	.815	2.55	.758	100
110	3.02	1.07	2.94	1.01	2.90	.970	2.81	.900	110
120	3.29	1.26	3.21	1.19	3.16	1.15	3.06	1.07	120
130	3.57	1.46	3.48	1.38	3.42	1.32	3.31	1.23	130
140	3.84	1.68	3.74	1.58	3.69	1.52	3.57	1.41	140
150	4.11	1.90	4.01	1.80	3.95	1.73	3.83	1.61	150
160	4.39	2.14	4.28	2.02	4.21	1.94	4.08	1.81	160
170	4.66	2 40	4.55	2.26	4.48	2.17	4.33	2.02	170
180	4.94	2.67	4.81	2.51	4.74	2.42	4.58	2.25	180
190	5.21	2.95	5.08	2.78	5.00	2.67	4.84	2.48	190
200	5.49	3.24	5.35	3.05	5.27	2.93	5.10	2.73	200
220	6.04	3.88	5.89	3.65	5.80	3.51	5.61	3.26	220
240	6.59	4.55	6.42	4.29	6.32	4.12	6.12	3.84	240
260	7.14	5.27	6.95	4.96	6.85	4.78	6.63	4.44	260
280	7.69	6.02	7.49	5.67	7.38	5.46	7.14	5.08	280
300	8.24	6.86	8.02	6.47	7.90	6.22	7.65	5.78	300
350	9.60	9.12	9.36	8.60	9.22	8.26	8.92	7.67	350
400	11.0	11.7	10.7	11.1	10.5	10.6	10.2	9.82	400
450	12.4	14.5	12.0	13.7	11.9	13.2	11.5	12.2	450
500	13.7	17.6	13.4	16.6	13.2	15.9	12.8	14.8	500
550	15.1	21.0	14.7	19.8	14.5	19.1	14.1	17.7	550
600	16.5	24.8	16.0	23.4	15.8	22.4	15.3	20.8	600
650	17.9	28.6	17.4	27.2	17.1	26.0	16.6	24.2	650
700	19.2	33.0	18.7	31.2	18.4	29.9	17.9	27.7	700
750	20.6	37.5	20.1	35.3	19.8	33.8	19.1	31.6	750
800	22.0	42.1	21.4	39.9	21.1	38.1	20.4	35.5	800
850	23.3	47.0	22.8	44.7	22.4	42.6	21.7	39.6	850
900	24.7	52.4	24.1	49.6	23.7	47.3	23.0	44.1	900
950	26.1	58.1	25.4	54.9	25.0	52.3	24.2	48.9	950
1000	27.4	63.6	26.8	60.3	26.4	57.6	25 5	53.6	1000
1100	30.2	75.8	29.4	71.5	29.0	68.7	28.1	63.9	1100
1200	32.9	89.4	32.1	84.3	31.6	81.0	30.6	75.4	1200
1300	35.7	103.	34.8	97.4	34.2	93.5	33.1	87.0	1300
1400	38.4	119.	37.4	112.	36.9	108.	35.7	100.	1400
1500	41.1	135.	40.1	127.	39.5	122.	38.3	114.	1500
1600	43.9	152.	42.8	143.	42.1	138.	40.8	128.	1600
1800	49.4	189.	48.1	178.	47.4	171.	45.8	159.	1800
2000	54.9	229.	53.5	216.	52.7	208.	51.0	193.	2000
2200	60.4	274.	58.9	258.	58.0	249.	56.1	231.	2200

Friction Losses in Copper and Brass Tubing and Pipe; C=130

5 Inch

Flow — US gal per min	Type K Tubing 4.805″ Inside Dia. .160″ Wall Thk.		Type L Tubing 4.875″ Inside Dia. .125″ Wall Thk.		Type M Tubing 4.907″ Inside Dia. .109″ Wall Thk.		Pipe 5.063″ Inside Dia. .250″ Wall Thk.		Flow — US gal per min
	Velocity ft./sec.	Head Loss ft./100ft.	Velocity ft./sec.	Head Loss ft./100ft.	Velocity ft./sec.	Head Loss ft./100ft.	Velocity ft./sec.	Head Loss ft./100ft.	
150	2.64	.657	2.58	.632	2.53	.592	2.38	.507	150
160	2.82	.740	2.75	.711	2.70	.666	2.54	.571	160
170	3.00	.827	2.92	.794	2.87	.745	2.70	.640	170
180	3.17	.920	3.09	.883	3.04	.828	2.86	.710	180
190	3.35	1.02	3.26	.975	3.21	.914	3.02	.785	190
200	3.53	1.12	3.44	1.07	3.38	1.01	3.18	.862	200
220	3.88	1.33	3.78	1.28	3.72	1.20	3.50	1.03	220
240	4.24	1.57	4.12	1.50	4.05	1.41	3.81	1.21	240
260	4.59	1.82	4.46	1.74	4.39	1.64	4.14	1.41	260
280	4.94	2.09	4.81	2.00	4.73	1.88	4.45	1.61	280
300	5.29	2.37	5.15	2.27	5.07	2.13	4.76	1.84	300
350	6.17	3.15	6.01	3.02	5.91	2.83	5.56	2.43	350
400	7.05	4.04	6.87	3.87	6.75	3.63	6.35	3.10	400
450	7.94	5.02	7.73	4.81	7.60	4.52	7.15	3.87	450
500	8.81	6.09	8.59	5.84	8.45	5.47	7.95	4.69	500
550	9.70	7.27	9.45	6.98	9.29	6.55	8.75	5.61	550
600	10.6	8.54	10.3	8.20	10.1	7.68	9.54	6.59	600
650	11.5	9.91	11.2	9.51	11.0	8.91	10.3	7.79	650
700	12.4	11.4	12.0	10.9	11.8	10.2	11.1	8.79	700
750	13.2	12.9	12.9	12.4	12.7	11.6	11.9	9.98	750
800	14.1	14.5	13.7	13.9	13.5	13.1	12.7	11.2	800
850	15.0	16.3	14.6	15.6	14.4	14.7	13.5	12.6	850
900	15.9	18.1	15.5	17.4	15.2	16.3	14.3	14.0	900
950	16.8	20.0	16.3	19.2	16.1	18.0	15.1	15.5	950
1000	17.6	22.0	17.2	21.2	16.9	19.8	15.9	17.0	1000
1100	19.4	26.2	18.9	25.1	18.6	23.6	17.5	20.2	1100
1200	21.2	30.8	20.6	29.5	20 3	27.7	19.1	23.7	1200
1300	22.9	35.7	22.4	34.2	22.0	32.1	20.6	27.5	1300
1400	24.7	40.9	24.0	39.2	23.7	36.8	22.2	31.5	1400
1500	26.4	46.6	25.8	44.7	25.4	41.8	23.8	35.9	1500
1600	28.2	52.4	27.5	50.3	27.0	47.2	25.4	40.5	1600
1800	31.8	65.3	30.9	62.7	30.4	58.7	28.6	50.3	1800
2000	35.3	79.2	34.4	76.1	33.8	71.2	31.8	61.0	2000
2200	38.8	94.5	37.8	90.7	37.2	85.0	35.0	73.1	2200
2400	42.4	111.	41.2	107.	40.5	99.8	38.1	86.0	2400
2600	45.9	129.	44.6	124.	44.0	116.	41.4	99.4	2600
2800	49.4	148.	48.1	142.	47.3	133.	44.5	113.7	2800
3000	52.9	168.	51.5	161.	50.7	151.	47.6	130.5	3000

Friction Losses in Copper and Brass Tubing and Pipe; C = 130

6 Inch

Flow — US gal per min	Type K Tubing 5.741" Inside Dia. .192" Wall Thk. Velocity ft./sec.	Type K Tubing Head Loss ft./100ft.	Type L Tubing 5.845" Inside Dia. .140" Wall Thk. Velocity ft./sec.	Type L Tubing Head Loss ft./100ft.	Type M Tubing 5.881" Inside Dia. .122" Wall Thk. Velocity ft./sec.	Type M Tubing Head Loss ft./100ft.	Pipe 6.125" Inside Dia. .250" Wall Thk. Velocity ft./sec.	Pipe Head Loss ft./100ft.	Flow — US gal per min
240	2.98	.658	2.87	.602	2.84	.585	2.61	.475	240
260	3.22	.762	3.11	.697	3.07	.677	2.83	.550	260
280	3.48	.876	3.35	.802	3 31	.779	3.05	.629	280
300	3.72	.996	3.58	.912	3.54	.885	3.26	.722	300
350	4.35	1.32	4.19	1.21	4.14	1.17	3.81	.952	350
400	4.97	1.69	4.79	1.55	4.72	1.51	4.35	1.22	400
450	5.59	2.11	5.38	1.93	5.31	1.87	4.90	1.52	450
500	6.20	2.56	5.98	2.34	5.90	2.27	5.44	1.84	500
550	6.82	3.05	6.57	2.79	6.50	2.71	5.98	2.20	550
600	7.45	3.59	7.17	3.28	7.10	3.19	6.53	2.58	600
650	8.07	4.16	7.76	3.81	7.68	3.70	7.07	2.99	650
700	8.69	4.87	8.36	4.36	8.27	4.24	7.61	3.45	700
750	9.31	5.42	8.96	4.96	8.86	4.82	8.15	3.91	750
800	9.93	6.10	9.56	5.58	9.45	5.42	8.70	4.40	800
850	10.6	6.83	10.2	6.25	10.0	6.07	9.25	4.94	850
900	11.2	7.61	10.8	6.95	10.6	6.75	9.79	5.46	900
950	11.8	8.39	11.4	7.68	11.2	7.46	10.3	6.06	950
1000	12.4	9.24	12.0	8.45	11.8	8.20	10.9	6.64	1000
1100	13.7	11.0	13.2	10.1	13.0	9.78	12.0	7.91	1100
1200	14.9	12.9	14.3	11.8	14.2	11.5	13.1	9.30	1200
1300	16.1	15.0	15.5	13.7	15.4	13.3	14.1	10.8	1300
1400	17.4	17.2	16.7	15.7	16.5	15.3	15.2	12 4	1400
1500	18.6	19.5	17.9	17.9	17.7	17.4	16.3	14.1	1500
1600	19.9	22.0	19.1	20.2	18.9	19.6	17.4	15.8	1600
1800	22.4	27.4	21.5	25.1	21.2	24.4	19.6	19.7	1800
2000	24.8	33.2	23.9	30.4	23.6	29.6	21.8	23.9	2000
2200	27.3	39.6	26.3	36.3	26.0	35.2	23.9	28.6	2200
2400	29.8	46.6	28.7	42.7	28.4	41.4	26.1	33.7	2400
2600	32.3	54.0	31.1	49.7	30.7	48.1	28.3	38.9	2600
2800	34.8	62.0	33.5	56.7	33.1	55.2	30.4	44.5	2800
3000	37.2	70.3	35.8	64.3	35.4	62.5	32.6	50.6	3000
3200	39.7	79.2	38.2	72.6	37.8	70.5	34.8	57.0	3200
3400	42.2	88.8	40.6	81.2	40.1	78.9	37.0	63.9	3400
3600	44.7	98.7	43.0	90.4	42.5	87.7	39.2	70.9	3600
3800	47.1	109.	45.4	99.8	44.9	96.8	41.4	78.4	3800
4000	49.6	120.	47.8	110.	47.2	107.	43.5	86.0	4000
4200	52.1	131.	50.1	120.	49.6	117.	45.7	94.6	4200
4400	54.6	143.	52.5	131.	52.0	127.	47.9	103.	4400

Friction Losses in Copper and Brass Tubing and Pipe; C=130

8 Inch

Flow — US Gal Per Min	Type K Tubing 7.583″ Inside Dia. .271″ Wall Thk.		Type L Tubing 7.725″ Inside Dia. .200″ Wall Thk.		Type M Tubing 7.785″ Inside Dia. .170″ Wall Thk.		Pipe 8.000″ Inside Dia. .3125″ Wall Thk.		Flow — US Gal Per Min
	Velocity ft./sec.	Head Loss ft./100ft.	Velocity ft./sec.	Head Loss ft./100ft.	Velocity ft./sec.	Head Loss ft./100ft.	Velocity ft./sec.	Head Loss ft./100ft.	
500	3 55	.654	3.42	.602	3.37	.579	3.19	.508	500
550	3.91	.780	3.76	.718	3.71	.692	3.51	.608	550
600	4.26	.916	4.10	.843	4.05	.813	3.83	.714	600
650	4.61	1.06	4.44	.978	4.39	.943	4.15	828	650
700	4.97	1.22	4.78	1.12	4.72	1.08	4.46	.950	700
750	5.32	1.39	5.12	1.27	5.06	1.23	4.79	1.08	750
800	5.68	1.56	5.46	1.43	5.40	1.38	5.10	1.21	800
850	6.04	1.75	5.80	1.61	5.73	1.55	5.42	1.36	850
900	6.39	1.95	6.15	1.79	6.06	1.72	5.74	1.51	900
950	6.75	2.14	6.49	1.97	6.40	1.90	6.05	1.67	950
1000	7.10	2.36	6.84	2.17	6.74	2.09	6.38	1.84	1000
1100	7.81	2.81	7.52	2.59	7.42	2.50	7.01	2.19	1100
1200	8.52	3.30	8.20	3.04	8.10	2.93	7.65	2.57	1200
1300	9.24	3.84	8.88	3.53	8.76	3.40	8.30	2.98	1300
1400	9.95	4.40	9.56	4.04	9.44	3.90	8.93	3.42	1400
1500	10.7	5.00	10.3	4.60	10.1	4.43	9.56	3.89	1500
1600	11.4	5 63	10.9	5.18	10.8	4.99	10.2	4.38	1600
1800	12.8	7.01	12.3	6.44	12.1	6.21	11.5	5.46	1800
2000	14.2	8.50	13.7	7.82	13.5	7.54	12.8	6.62	2000
2200	15.6	10.1	15.0	9.32	14.9	8.98	14.	7.90	2200
2400	17.0	11.9	16.4	11.0	16.2	10.6	15.3	9.28	2400
2600	18.5	13.8	17.8	12.7	17.5	12.2	16.6	10.8	2600
2800	19.9	15.9	19.2	14.6	18.9	14.1	17.9	12.4	2800
3000	21.3	18.0	20.5	16.5	20.2	15.9	19.1	14.0	3000
3200	22.7	20.3	21.9	18.6	21.6	18.0	20.4	15.8	3200
3400	24.2	22.7	23.2	20.9	22.9	20.1	21.7	17.7	3400
3600	25.6	25.2	24.6	23.2	24.3	22.4	23.0	19.6	3600
3800	27.0	27.8	26.0	25.6	25.6	24.7	24.2	21.7	3800
4000	28.4	30.7	27.3	28.2	27.0	27.2	25.5	23.9	4000
4200	29.8	33.6	28.7	30.8	28.3	29.7	26.8	26.1	4200
4400	31.2	36.6	30.0	33.6	29.7	32.4	28.0	28.5	4400
4600	32.7	39.7	31.4	36.5	31.0	35.2	29.4	30.9	4600
4800	34.1	43.0	32.8	39.5	32.4	38.1	30.6	33.5	4800
5000	35.5	46.4	34.2	42.6	33.7	41.1	31.9	36.1	5000
5500	39.1	55.3	37.6	50.8	37.1	49.0	35.1	43.0	5500
6000	42.6	65.0	41.0	59.8	40.5	57.6	38.3	50.6	6000
6500	46.1	73.5	44.4	67.6	43.9	65.2	41.5	57.2	6500
7000	49.7	86.4	47.9	79.5	47.2	76.6	44.6	67.3	7000

FLOW THROUGH ORIFICES AND NOZZLES

Approximate discharge through orifice or nozzle.

$$Q = 19.636\ Kd^2 \sqrt{h} \sqrt{\frac{1}{1-\left(\frac{d}{D}\right)^4}} \qquad \text{where } \frac{d}{D} \text{ is greater than .3}$$

$$Q = 19.636\ Kd^2 \sqrt{h} \qquad \text{where } \frac{d}{D} \text{ is less than .3}$$

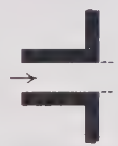
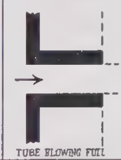
Q = flow, in gpm

d = dia of orifice or nozzle opening, in.

h = differential head at orifice, in feet of liquid.

D = dia of pipe in which orifice is placed.

K = discharge coefficient (typical values below for water)

RE-ENTRANT TUBE	SHARP-EDGED	SQUARE EDGED	RE-ENTRANT TUBE	SQUARE EDGED	WELL ROUNDED
 LENGTH = 1/2 to 1 DIA.		 STREAM CLEARS SIDES	 LENGTH = 2-1/2 DIA.	 TUBE FLOWING FULL	
K=.52	K=.61	K=.61	K=.73	K=.82	K=.98

Approximate flow through Venturi tube.

$$Q = 19.05\ d^2 \sqrt{H} \sqrt{\frac{1}{1-\left(\frac{d}{D}\right)^4}} \qquad \text{for any Venturi tube}$$

$$Q = 19.17\ d^2 \sqrt{H} \qquad \text{for a Venturi tube in which } d = 1/3\ D$$

Q = flow, in gpm

d = dia. of venturi throat, in.

D = dia. of main pipe, in.

H = diff. in head between upstream end and throat (ft.).

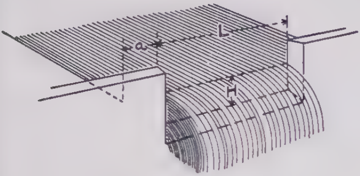
These formulae are suitable for any liquid. However, K varies with liquid viscosity, the values given here being for water. A value of 32.174 ft. per sec was used for the acceleration of gravity and a value of 7.48 gal per cu ft in computing the constants. A value of .97 was used for K in the Venturi formulae.

Theoretical Discharge of Nozzles in U S Gallons Per Minute

Head lb	Head feet	Velocity of disch ft/sec	Diameter of Nozzle in Inches 1/16	1/8	3/16	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8
10	23.1	38.6	0.37	1.48	3.32	5.91	13.3	23 6	36.9	53.1	72.4	94.5	120	148	179
15	34.6	47.25	0.45	1.81	4.06	7.24	16.3	28.9	45.2	65.0	88.5	116.	147	181	219
20	46.2	54.55	0.52	2.09	4.69	8.35	18.8	33.4	52.2	75.1	102.	134.	169	209	253
25	57.7	61.0	0.58	2.34	5.25	9.34	21.0	37.3	58.3	84.0	114.	149.	189	234	283
30	69.3	66.85	0.64	2.56	5.75	10.2	23.0	40.9	63.9	92.0	125.	164.	207	256	309
35	80.8	72.2	0 69	2 77	6.21	11.1	24.8	44.2	69.0	99.5	135.	177.	224	277	334
40	92.4	77.2	0.74	2.96	6.64	11.8	26.6	47.3	73.8	106.	145.	188.	239	296	357
45	103.9	81.8	0 78	3 13	7.03	12.5	28.2	50.1	78.2	113.	153.	200.	253	313	379
50	115 5	86.25	0 83	3.30	7.41	13.2	29.7	52.8	82.5	119.	162.	211.	267	330	399
55	127 0	90 5	0 87	3.46	7.77	13.8	31.1	55.3	86.4	125.	169.	221.	280	346	418
60	138 6	94.5	0 90	3.62	8 12	14 5	32.5	57.8	90.4	130.	177.	231.	293	362	438
65	150 1	98.3	0 94	3 77	8 45	15.1	33.8	60.2	94.0	136.	184.	241.	305	376	455
70	161.7	102.1	0 98	3 91	8.78	15 7	35.2	62.5	97.7	141.	191.	250.	317	391	473
75	173.2	105.7	1.01	4.05	9.08	16.2	36.4	64.7	101.	146.	198.	259.	327	404	489
80	184.8	109.1	1.05	4.18	9.39	16.7	37.6	66.8	104.	150.	205.	267.	338	418	505
85	196.3	112.5	1.08	4 31	9 67	17.3	38.8	68.9	108.	155.	211.	276.	349	431	521
90	207.9	115.8	1.11	4.43	9 95	17.7	39 9	70.8	111.	160.	217.	284.	359	443	536
95	219.4	119 0	1.14	4.56	10.2	18.2	41.0	72.8	114.	164.	223.	292.	369	456	551
100	230.9	122.0	1.17	4.67	10.5	18.7	42.1	74.7	117.	168.	229.	299.	378	467	565
105	242.4	125 0	1.20	4.79	10.8	19.2	43.1	76.5	120.	172.	234.	306.	388	479	579
110	254.0	128.0	1.23	4.90	11 0	19.6	44.1	78.4	122.	176.	240.	314.	397	490	593
115	265 5	130.9	1.25	5.01	11.2	20.0	45.1	80.1	125.	180.	245.	320.	406	501	606
120	277.1	133.7	1.28	5.12	11.5	20.5	46.0	81.8	128.	184.	251.	327.	414	512	619
130	300.2	139.1	1.33	5 33	12.0	21.3	48.0	85.2	133.	192.	261.	341.	432	533	645
140	323.3	144.3	1.38	5.53	12.4	22.1	49.8	88.4	138.	199.	271.	354.	448	553	668
150	346.4	149.5	1.43	5.72	12.9	22.9	51.6	91.5	143.	206.	280.	366.	463	572	692
175	404.1	161.4	1.55	6.18	13.9	24.7	55.6	98.8	154.	222.	302.	395.	500	618	747
200	461.9	172.6	1.65	6 61	14.8	26.4	59.5	106.	165.	238.	323.	423.	535	660	799
250	577.4	193.0	1.85	7 39	16.6	29.6	66 5	118.	185.	266.	362.	473.	598	739	894
300	692.8	211.2	2.02	8.08	18.2	32.4	72.8	129.	202.	291.	396.	517.	655	808	977

Head lb	Head feet	Velocity of disch ft/sec	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/2	4	4 1/2	5	5 1/2	6
10	23.1	38.6	213	289	378	479	591	714	851	1158	1510	1915	2365	2855	3405
15	34.6	47.25	260	354	463	585	723	874	1041	1418	1850	2345	2890	3490	4165
20	46.2	54.55	301	409	535	676	835	1009	1203	1638	2135	2710	3340	4040	4810
25	57 7	61.0	336	458	598	756	934	1128	1345	1830	2385	3025	3730	4510	5380
30	69.3	66.85	368	501	655	828	1023	1236	1473	2005	2615	3315	4090	4940	5895
35	80.8	72.2	398	541	708	895	1106	1335	1591	2168	2825	3580	4415	5340	6370
40	92.4	77.2	425	578	756	957	1182	1428	1701	2315	3020	3830	4725	5610	6810
45	103.9	81.8	451	613	801	1015	1252	1512	1802	2455	3200	4055	5000	6050	7120
50	115 5	86 25	475	647	845	1070	1320	1595	1900	2590	3375	4275	5280	6380	7600
55	127.0	90.4	498	678	886	1121	1385	1671	1991	2710	3540	4480	5530	6690	7970
60	138 6	94.5	521	708	926	1172	1447	1748	2085	2835	3700	4685	5790	6980	8330
65	150 1	98.3	542	737	964	1220	1506	1819	2165	2950	3850	4875	6020	7270	8670
70	161.7	102.1	563	765	1001	1267	1565	1888	2250	3065	4000	5060	6250	7560	9000
75	173.2	105.7	582	792	1037	1310	1619	1955	2330	3170	4135	5240	6475	7820	9320
80	184.8	109.1	602	818	1070	1354	1672	2020	2405	3280	4270	5410	6690	8080	9630
85	196.3	112.5	620	844	1103	1395	1723	2080	2480	3375	4400	5575	6890	8320	9920
90	207.9	115.8	638	868	1136	1436	1773	2140	2550	3475	4530	5740	7090	8560	10210
95	219.4	119 0	656	892	1168	1476	1824	2200	2625	3570	4655	5900	7290	8800	10500
100	230.9	122.0	672	915	1196	1512	1870	2255	2690	3660	4775	6050	7470	9030	10770
105	242.4	125 0	689	937	1226	1550	1916	2312	2755	3750	4890	6200	7650	9260	11020
110	254 0	128 0	705	960	1255	1588	1961	2366	2820	3840	5010	6340	7840	9470	11300
115	265.5	130.9	720	980	1282	1621	2005	2420	2885	3930	5120	6490	8010	9680	11550
120	277.1	133.7	736	1002	1310	1659	2050	2470	2945	4015	5225	6630	8180	9900	11800
130	300.2	139.1	767	1043	1365	1726	2132	2575	3070	4175	5450	6900	8530	10300	12290
140	323 3	144.3	795	1082	1415	1790	2212	2650	3180	4330	5650	7160	8850	10690	12730
150	346.4	149.5	824	1120	1466	1853	2290	2760	3295	4485	5850	7410	9150	11070	13200
175	404.1	161.4	890	1210	1582	2000	2473	2985	3560	4840	6310	8000	9890	11940	14250
200	461 9	172.6	950	1294	1691	2140	2645	3190	3800	5175	6760	8550	10580	12770	15220
250	577.4	193.0	1063	1447	1891	2392	2955	3570	4250	5795	7550	9570	11820	14290	17020
300	692.8	211.2	1163	1582	2070	2615	3235	3900	4650	6330	8260	10480	12940	15620	18610

The actual quantity discharged by a nozzle will be less than above table. A well tapered smooth nozzle may be assumed to give 97 to 99% of the values in the tables.



Discharge From Rectangular Weir with End Contractions

Figures in Table are in Gallons Per Minute

Head (H) in Inches	Length (L) of weir in feet 1	3	5	Additional g.p.m. for each ft. over 5 ft.	Head (H) in Inches	Length (L) of weir in feet 3	5	Additional g.p.m. for each ft. over 5 ft.
1	35.4	107.5	179.8	36 05	8	2338	3956	814
1¼	49.5	150.4	250.4	50.4	8¼	2442	4140	850
1½	64.9	197	329 5	66.2	8½	2540	4312	890
1¾	81	248	415	83.5	8¾	2656	4511	929
2	98.5	302	506	102	9	2765	4699	970
2¼	117	361	605	122	9¼	2876	4899	1011
2½	136.2	422	706	143	9½	2985	5098	1051
2¾	157	485	815	165	9¾	3101	5288	1091
3	177.8	552	926	187	10	3216	5490	1136
3¼	199.8	624	1047	211	10½	3480	5940	1230
3½	222	695	1167	236	11	3716	6355	1320
3¾	245	769	1292	261	11½	3960	6780	1410
4	269	846	1424	288	12	4185	7165	1495
4¼	293.6	925	1559	316	12½	4430	7595	1575
4½	318	1006	1696	345	13	4660	8010	1660
4¾	344	1091	1835	374	13½	4950	8510	1780
5	370	1175	1985	405	14	5215	8980	1885
5¼	395.5	1262	2130	434	14½	5475	9440	1985
5½	421.6	1352	2282	465	15	5740	9920	2090
5¾	449	1442	2440	495	15½	6015	10400	2165
6	476.5	1535	2600	528	16	6290	10900	2300
6¼		1632	2760	560	16½	6565	11380	2410
6½		1742	2920	596	17	6925	11970	2520
6¾		1826	3094	630	17½	7140	12410	2640
7		1928	3260	668	18	7410	12900	2745
7¼		2029	3436	701.5	18½	7695	13410	2855
7½		2130	3609	736	19	7980	13940	2970
7¾		2238	3785	774	19½	8280	14460	3090

This table is based on Francis formula:

$$Q=3.33\ (L-0.2H)\ H^{1.5}$$

which

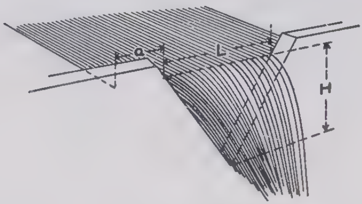
Q=cu. ft. of water flowing per second.

L=length of weir opening in feet. (should be 4 to 8 times H).

H=head on weir in feet (to be measured at least 6 ft. back of weir opening).

a=should be at least 3 H.

Discharge from Triangular Notch Weirs with End Contractions



Head (H) in Inches	Flow in Gallons Per Min. 90° Notch	Flow in Gallons Per Min. 60° Notch	Head (H) in Inches	Flow in Gallons Per Min. 90° Notch	Flow in Gallons Per Min. 60° Notch	Head (H) in Inches	Flow in Gallons Per Min. 90° Notch	Flow in Gallons Per Min. 60° Notch
1	2.19	1.27	6¾	260	150	15	1912	1104
1¼	3.83	2.21	7	284	164	15½	2073	1197
1½	6.05	3.49	7¼	310	179	16	2246	1297
1¾	8.89	5.13	7½	338	195	16½	2426	1401
2	12.4	7.16	7¾	367	212	17	2614	1509
2¼	16.7	9.62	8	397	229	17½	2810	1623
2½	21.7	12.5	8¼	429	248	18	3016	1741
2¾	27.5	15.9	8½	462	267	18½	3229	1864
3	34.2	19.7	8¾	498	287	19	3452	1993
3¼	41.8	24.1	9	533	308	19½	3684	2127
3½	50.3	29.0	9¼	571	330	20	3924	2266
3¾	59.7	34.5	9½	610	352	20½	4174	2410
4	70.2	40.5	9¾	651	376	21	4433	2560
4¼	81.7	47.2	10	694	401	21½	4702	2715
4½	94.2	54.4	10½	784	452	22	4980	2875
4¾	108	62.3	11	880	508	22½	5268	3041
5	123	70.8	11½	984	568	23	4565	3213
5¼	139	80.0	12	1094	632	23½	5873	3391
5½	156	89.9	12½	1212	700	24	6190	3574
5¾	174	100	13	1337	772	24½	6518	3763
6	193	112	13½	1469	848	25	6855	3958
6¼	214	124	14	1609	929			
6½	236	136	14½	1756	1014			

Based on formula:

$$Q = (C)\ (4/15)\ (L)\ (H)\sqrt{2gH}$$

in which Q = flow of water in cu. ft. per sec.

L = width of notch in ft. at H distance above apex.

H = head of water above apex of notch in ft.

C = constant varying with conditions, .57 being used for this table.

a = should be not less than ¾ L.

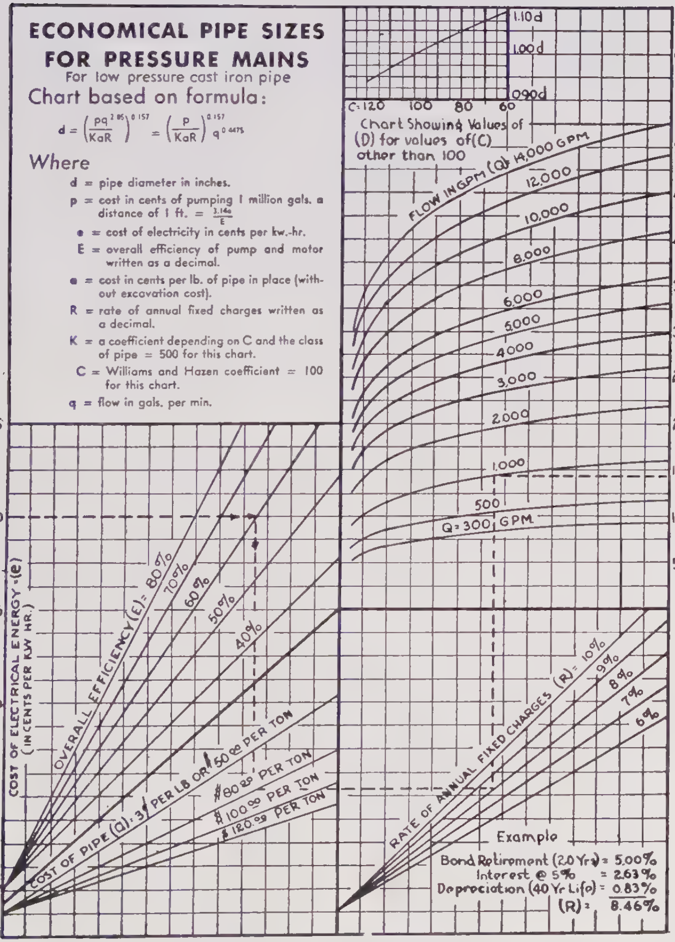
For 90° notch the formula becomes

$$Q = 2.4381H^{5/2}$$

For 60° notch the formula becomes

$$Q = 1.4076\ H^{5/2}$$

ECONOMICAL PIPE SIZES



Courtesy of George B. Gascaigne, Consulting Engineer, Cleveland. Compiled by R. G. Hornberger, W. L. Leach and J. W. Avery

Irrigation Table

Gal min	Cu ft sec	Cu ft min	Number of Acres covered in twelve hours pumping. 1 in deep	2 in deep	3 in deep	4 in deep	6 in deep	8 in deep	10 in deep	12 in deep
20	.0446	2.675	.529	.2645	.1765	.1324	.08825	.06625	.0529	.04415
50	.1112	6.68	1.328	.664	.4425	.332	.2213	.166	.1328	.1105
100	.2225	13.37	2.96	1.325	.883	.6625	.442	.3313	.265	.221
150	.3345	20.05	3.98	1.991	1.328	.995	.664	.4975	.398	.332
225	.502	30.05	5.97	2.985	1.990	1.492	.994	.747	.597	.4975
300	.668	40.01	7.96	3.980	2.655	1.99	1.327	.995	.796	.663
400	.891	53.40	10.61	5.305	3.535	2.652	1.770	1.328	1.061	.884
700	1.560	93.50	18.58	9.28	6.18	4.64	3.095	2.32	1.858	1.548
900	2.008	120.40	23.85	11.95	7.96	5.97	3.98	2.975	2.385	1.99
1200	2.675	160.50	31.82	15.92	10.61	7.95	5.305	3.975	3.182	2.65
1600	3.565	213.50	42.35	21.20	14.15	10.61	7.075	5.305	4.235	2.535
3000	6.68	400.50	79.50	39.75	26.50	19.88	13.25	9.94	7.95	6.625
4500	10.03	602.00	119.30	59.70	39.75	29.85	19.90	14.93	11.93	9.95
6000	13.36	802.00	159.10	79.60	53.00	39.75	26.52	18.89	15.91	13.26
7000	15.61	936.00	185.70	92.80	61.90	46.45	30.95	23.20	18.57	15.47
8500	18.95	1137.00	225.50	112.80	75.20	56.35	37.60	28.19	22.55	18.79
10000	22.25	1337.00	265.00	132.50	88.30	66.25	44.20	33.15	26.50	22.10
14000	31.15	1871.00	371.00	185.50	123.70	92.75	61.80	46.35	37.10	30.95

1 Acrefoot = 1 acre covered to a depth of 1 ft = 43,560 cubic feet.

3

CHAPTER III

MISCELLANEOUS LIQUIDS

CONTENTS OF CHAPTER III

Liquids Other Than Water

Liquids Other than Water

Viscosity is the internal friction of a liquid tending to reduce flow. As a measure of the coefficient of viscosity, units are used in terms of force required to move a unit area a unit distance. Absolute viscosity is in terms of C G S units, the force of one dyne required to move one square centimeter of liquid a distance of one centimeter. This unit is called a poise. Centipoises are 1/100th of a poise.

Various type of viscosimeters are used to measure viscosity. These do not give results in terms of absolute viscosity, but usually in terms of the number of seconds it takes a given quantity of fluid to flow through a tube of given cross-section. Strictly speaking, these viscosimeters give a measure of the coefficient of kinematic viscosity. Absolute viscosity is the kinematic viscosity multiplied by the density; or, abs visc (in centipoises) = kin visc (in centistokes) × density (in gr per cu cm). Since density in grams per cu cm is identical numerically with specific gravity referred to water at 39.2°F as 1.0, the formula for practical purposes can be written: abs visc = kin visc × sp gr.

When viscosity of a liquid is given, the temperature at which it was determined must also be given, together with the viscosity units used.

Water has a viscosity of 31. 5 S S U (1.1 centistokes) at 60°F. By comparison, certain oils may have viscosities of 3000 S S U (650 centistokes).

Specific gravity is the term indicating the density of a liquid with reference to water, which is called 1.0. This is usually taken for water at 60°F. but is sometimes taken at point of maximum density for water, 39.2°F. For practical purposes, sp. gr. referred to either base is the same.

Gravity may be given in either degrees Baume, degrees API (for oils), degrees Brix (for sugar), or specific gravity directly. All are definitely related.

Increase in temperature decreases viscosity, decreases specific gravity and increases the volume.

The capacity of a barrel is different in various industries. For instance

1 bbl. of beer	=31 U S gallons.
1 bbl. of whiskey	=45 U S gallons.
1 bbl. of oil	=42 U S gallons.

CENTRIFUGAL PUMP PERFORMANCE
with Viscous Liquids

The following examples will illustrate the use of the curves. *In computations for multi-stage pumps, use head per stage.*

EXAMPLE A. SELECTING A PUMP

Select a pump to deliver 750 gpm at 100 ft. total head with a liquid having a viscosity of 1000 SSU and specific gravity of .90 at pumping temperature.

Enter chart at 750 gpm, go up to 100 ft. head, over to 1000 SSU and up to correction factors. (For this calculation use C_H from curve marked "1.0 x Q_N".)

$C_Q = .95$ $C_E = .64$ C_H for "1.0 x Q_N" $= .92$

Equivalent water conditions, obtained by dividing the viscous conditions by the applicable correction factors, will be 790 gpm and 108.7 ft.

If the pump selected for these equivalent water conditions has an efficiency of 81%, viscous efficiency will be C_E x 81% or about 52%.

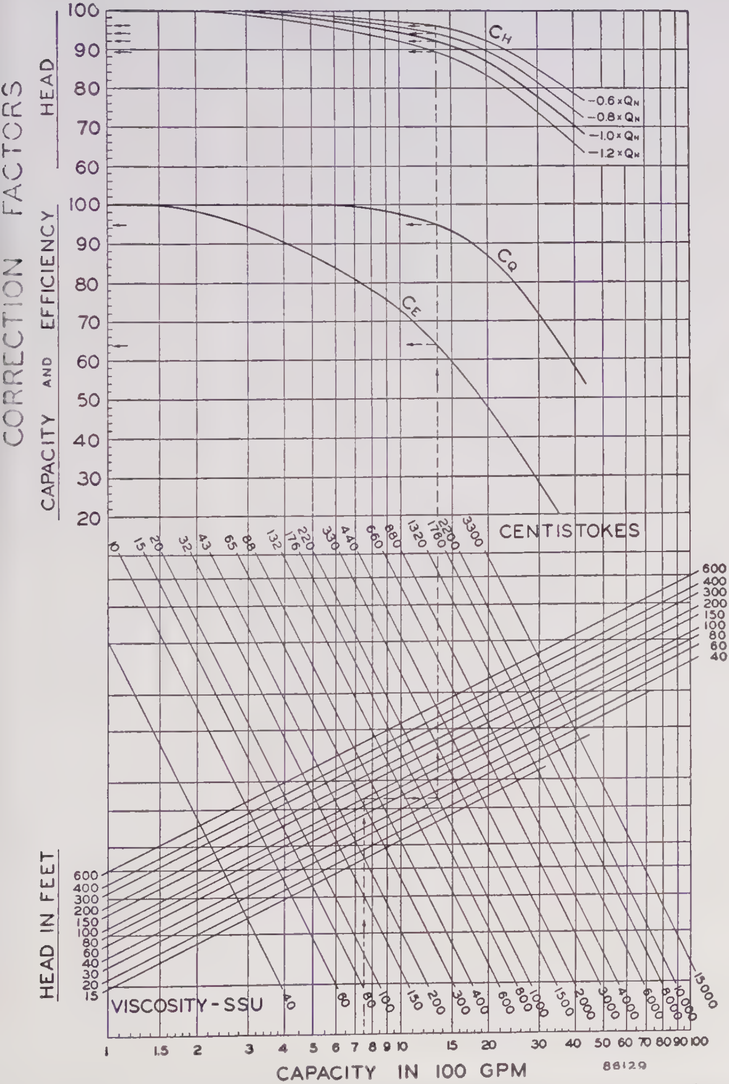
$$\text{Estimated bhp} = \frac{750 \times 100 \times .9}{3960 \times .52} = 32.8 \text{ hp}$$

EXAMPLE B. PERFORMANCE CORRECTION

Given the bhp, efficiency and head vs. capacity curves for a pump with water, correct these performance curves for oil with a specific gravity of .90 and viscosity of 1000 SSU at pumping temperature.

Determine the gpm (Q_N) for the point of best water efficiency. Tabulate 0.6 x Q_N, 0.8 x Q_N, 1.0 x Q_N, and 1.2 x Q_N for water. Read heads and efficiencies from the water curves at these values of gpm and tabulate. Entering the chart at Q_N, go upward to the head in ft. at flow Q_N, horizontally to 1000 SSU and vertically to the correction factors, reading one value of C_Q and C_E and four values of C_H for the four of Q_N. Multiplying the tabulated water values by these factors will give the corrected values for operation with the viscous fluid. Corrected head and efficiency curves may be plotted with these points and brake horsepower determined by use of the formula.

$$\text{bhp (viscous)} = \frac{\text{(viscous) capacity} \times \text{(viscous) head} \times \text{sp. gr.}}{3960 \times \text{(viscous) efficiency}}$$



Curve applicable only to centrifugal pumps of conventional design with open or closed impellers and adequate NPSH. Not good for axial- or mixed-flow pumps or non-uniform liquids.

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Specific Gravity and Viscosity of Liquids

Liquid	Boiling point at atm press °F	Specific gravity		Kinematic viscosity			Coordinates chart, pg 80	
		Temp °F	Water at 4°C=1	Temp °F	Centistokes	SSU	a	b
Acetaldehyde	69	68	.782	68	.295	—	3.0	0
Acetic acid	245	68	1.049	68	1.17	—	3.3	5.1
Acetone	133	68	.79	68	.41	—	2.8	1.5
Aero motor oil (typical)	—	60	.895	100	—	1100		
	—	—	——	210	—	95	2.7	12.2
Alcohol, allyl-n	207	68	.855	68	1.60	—	3.9	5.6
Alcohol, butyl-n	243	68	.81	68	3.64	38	3.3	7.3†
	243	158	.78	158	1.17	—	4.65	7.05††
Alcohol, ethyl-n (grain)	172	68	.789	68	1.52	—	3.35	5.67
Alcohol, methyl-n (wood)	151	68	.79	59	.74	—	3.8	3.8
Alcohol, propyl-n	207	68	.804	68	2.8	35	3.2	6.95
Ammonia (liquid)	−28	0	.662	0	.30	—	—	—
Aniline	363	68	1.022	68	4.37	40	4.2	7.15
Automobile crankcase oils, SAE 10	—	60	.88–94	130	—	90–120	3.0	10.7
SAE 20	—	60	.88–94	130	—	120–185	3.0	11.3
SAE 3	—	60	.88–94	130	—	185–225	3.0	11.65
SAE 40	—	60	.88–94	130	—	225–400	2.9	12.0
SAE 50	—	60	.88–94	210	—	80–105	2.8	12.2
SAE 60	—	60	.88–94	210	—	105–125	2.65	12.65
SAE 70	—	60	.88–94	210	—	125–150	2.6	12.7
Automobile transmission lub, SAE 80	—	60	.88–94	0	—	100,000 max	—	—
SEA 90	—	60	.88–94	100	—	800–1500	—	—
SAE 140	—	60	.88–94	210	—	120–200	—	—
SAE 250	—	60	.88–94	210	—	200 min	—	—
Beer	—	60	1.01	68	—	32 (est)	—	—
Benzol (Benzene)	176	68	.879	68	.744	—	3.6	3.85
Brine, calcium chloride, 25%	—	60	1.23	60	—	39	—	—
Brine, sodium chloride, 25%	—	60	1.19	60	—	34	—	—
Bromine	142	68	2.9	68	.34	—	—	—
Butyric acid-n	316	68	.959	68	1.61	—	3.0	5.95
Carbolic acid (phenol)	360	65	1.08	65	11.83	65	4.5	7.9
Carbon disulphide	115	68	1.263	68	.298	—	−.9	8.9*
Carbon tetrachloride	170	68	1.594	68	.612	—	4.0	3.25
Castor Oil	—	68	.96	68	—	4600	2.75	12.2
Chloroform	142	68	1.489	68	.38	—	3.05	1.2
Compounded steam cyl oil (5% tallow)	—	60	.90	110	—	1800	2.4	12.8
				210	—	145		
Decane-n	343	68	.73	68	1.24	—	2.95	5.35
Diethyl ether	94.4	68	.714	68	.32	—	3.0	.6
Ethyl acetate	171	68	.90	68	.49	—	3.7	2.5
Ethyl bromide	101	59	1.45	68	.27	—	−.2	8.3*
Ethylene bromide	269	68	2.18	68	.787	—	3.6	3.95
Ethylene chloride	183	68	1.246	68	.668	—	3.5	3.5
Formic acid	213	68	1.221	68	1.48	—	3.9	5.5

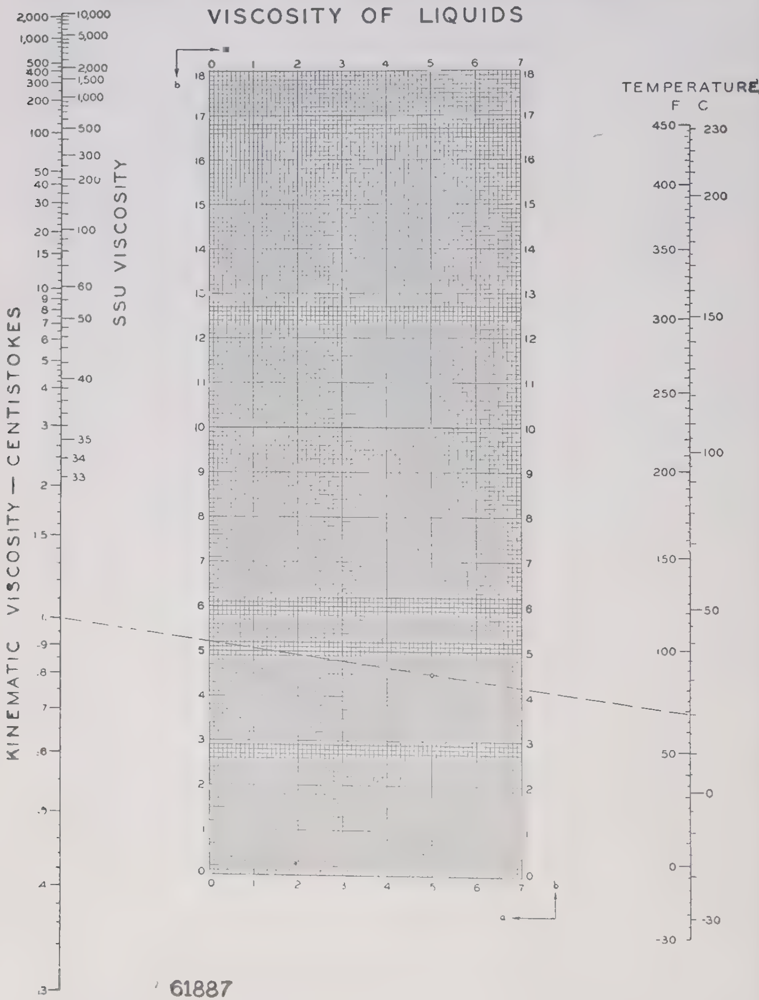
†Accurate for the range between 32 and 158°F.
††Accurate for the range between 139 and 158°F.
*Divide figure obtained with these coordinates by 10 to obtain viscosity in centistokes.

Specific Gravity and Viscosity of Liquids

Liquid	Boiling point at atm press °F	Specific gravity		Kinematic viscosity			Coordinates chart, pg 80	
		Temp °F	Water at 4°C—1	Temp °F	Centi stokes	SSU	a	b
Freon 11	—	70	1.49	70	.32	—	—	—
Freon 12	—	70	1.33	70	.21	—	—	—
Freon 21	—	70	1.37	70	.27	—	—	—
Fuel Oil, No. 1	—	60	.82–95	100	—	30–40	—	—
No. 2	—	60	.82–95	100	—	35–50	—	—
No. 3	—	60	.82–95	100	—	55 max	—	—
No. 5	—	60	.82–95	100	—	60–450	—	—
No. 6	—	60	.82–95	122	—	430–2900	—	—
Gasoline, typical (a)	—	6	.74	60	.88	—	3.15	4.15
(b)	—	6	.72	60	.64	—	3.7	3.2
(c)	—	6	.68	60	.46	—	2.6	1.7
Glycerine, 100%	554	68	1.26	68.6	—	2950	3.25	11.5
Glycerine and water, 50%	—	68	1.13	68	—	43	—	—
Glycol, Ethylene	—	68	1.125	70	17.8	88.4		
Heptane-n	209	68	.684	68	.60	—	2.9	3.1
Hexane-n	156	68	.66	68	.49	—	3.0	2.3
Hydrochloric acid, 31.5%	—	68	1.05	68	1.9	—	—	—
Kerosene	—	60	.78–.82	68	—	35	—	—
Lard oil	—	60	.91–.92	100	—	180–200	—	—
Linseed oil (raw)	538	60	.92–.94	100	—	143	2.0	11.1
Marine engine oil (20% blown rape)	—	60	.94	210	—	70	2.5	11.9
Methy acetate	135	68	.93	68	.44	—	3.1	1.6
Methy iodide	108	68	2.28	68	.213	—	.35	7.5*
Milk	—	68	1.02-1.04	68	—	32 est	—	—
Naphthelene	424	68	1.145	176	.9	—	—	—
Neatsfoot oil	—	60	.91–.92	60	107-123	—	—	—
Nitric acid, 60%	—	68	1.37	68	1.87	—	—	—
Nitrobenzene	412	68	1.203	68	1.67	—	3.1	6.0
Nonane-n	302	68	.718	68	.97	—	1.6	4.7
Octane-n	258	68	.70	68	.77	—	3.0	3.95
Olive oil	(570)	68	.91	68	93.0	—	2.4	11.4
Pentane-n	97	68	.63	68	.37	—	2.8	1.1
Petroleum ether (benzine)	—	60	.64	60	—	31 est	—	—
Propionic acid	286	68	.99	68	1.13	—	3.2	5.05
Quenching oil (typical)	—	60	.86–89	100	—	100–120	—	—
Rapeseed oil	—	68	.91	68	180	—	2.6	11.5
Soya bean oil	—	60	.924	60	86	—	2.1	11.3
Sperm oil	(209)	77	.88	100	21	—	2.3	10.7
Sugar, 20%	—	68	1.08	68		33.5	—	—
40%	—	68	1.18	68	5.3	43	—	—
60%	—	68	1.29	68	44	202	—	—
Sulfuric acid, 100%	640	68	1.83	68	14.6	76	—	—
95%	—	68	1.83	68	14.5	75	—	—
60%	—	68	1.50	68	4.4	41	—	—
Turbine oil (typical medium)	—	60	.91	100	—	270	—	—
Turpentine	320	60	.86–87	60	1.83	—	2.9	6.1
Water (fresh)	212	60	1.0	60	1.1	31.5	5.0	4.5
Water (sea)	—	60	1.03	60	—	31.5	—	—
Xyolene-o	287	68	87	68	93	—	2.8	4.5

*Divide figure obtained with these coordinates by 10 to obtain viscosity in centistokes.

VISCOSITY OF LIQUIDS



If viscosity is known at two temperatures, plot these points on the graph. The intersection of the lines from temperature to viscosity will give a point. Lines through this point will give viscosity at any other temperature. The point shown is for water. Other points are given in the tables pages 78 and 79. These data are approximate. However, coordinates have been given only for those liquids upon which consistent data over the normal temperature range was available.

United States Standard Baume Scales

Relation Between Baume Degrees and Specific Gravity

LIQUIDS HEAVIER THAN WATER

$$\text{Formula—sp gr} = \frac{145}{145 - {}^\circ\ \text{Baume}}$$

Baume degrees	Sp Gr 60°-60°F	Baume degrees	Sp Gr 60°-60°F	Baume degrees	Sp Gr 60°-60°F	Baume degrees	Sp Gr 60°-60°F
0	1.00000	20	1.16000	40	1.38095	60	1.70588
1	1.00694	21	1.16935	41	1.39423	61	1.72619
2	1.01399	22	1.17886	42	1.40777	62	1.74699
3	1.02113	23	1.18852	43	1.42157	63	1.76829
4	1.02837	24	1.19835	44	1.43564	64	1.79012
5	1.03571	25	1.20833	45	1.45000	65	1.81250
6	1.04317	26	1.21849	46	1.46465	66	1.83544
7	1.05072	27	1.22881	47	1.47959	67	1.85897
8	1.05839	28	1.23932	48	1.49485	68	1.88312
9	1.06618	29	1.25000	49	1.51042	69	1.90789
10	1.07407	30	1.26087	50	1.52632	70	1.93333
11	1.08209	31	1.27193	51	1.54255	71	1.95946
12	1.09023	32	1.28319	52	1.55914	72	1.98630
13	1.09848	33	1.29464	53	1.57609	73	2.01389
14	1.10687	34	1.30631	54	1.59341	74	2.04225
15	1.11538	35	1.31818	55	1.61111	75	2.07143
16	1.12403	36	1.33028	56	1.62921	76	2.10145
17	1.13281	37	1.34259	57	1.64773	77	2.13235
18	1.14173	38	1.35514	58	1.66667	78	2.16418
19	1.15079	39	1.36792	59	1.68605	79	2.19697

LIQUIDS LIGHTER THAN WATER

$$\text{Formula—sp gr} = \frac{140}{130 + {}^\circ\ \text{Baume}}$$

10	1.00000	30	0.87500	50	0.77778	70	0.70000
11	.99291	31	.86957	51	.77348	71	.69652
12	.98592	32	.86420	52	.76923	72	.69307
13	.97902	33	.85890	53	.76503	73	.68966
14	.97222	34	.85366	54	.76087	74	.68627
15	.96552	35	.84848	55	.75676	75	.68293
16	.95890	36	.84337	56	.75269	76	.67961
17	.95238	37	.83832	57	.74866	77	.67633
18	.94595	38	.83333	58	.74468	78	.67308
19	.93960	39	.82840	59	.74074	79	.66986
20	.93333	40	.82353	60	.73684	80	.66667
21	.92715	41	.81871	61	.73298	81	.66351
22	.92105	42	.81395	62	.72917	82	.66038
23	.91503	43	.80925	63	.72539	83	.65728
24	.90909	44	.80460	64	.72165	84	.65421
25	.90323	45	.80000	65	.71795	85	.65117
26	.89744	46	.79545	66	.71428	86	.64815
27	.89172	47	.79096	67	.71066	87	.64516
28	.88608	48	.78652	68	.70707	88	.64220
29	.88050	49	.78212	69	.70352	89	.63927

From Circular No. 59 Bureau of Standards.

Pounds per gallon and specific gravities corresponding to degrees A P I at 60°F

$$\text{Formula—sp gr} = \frac{141.5}{131.5 + {}^{\circ}\text{A P I}}$$

Deg API	TENTHS OF DEGREES									
	0	1	2	3	4	5	6	7	8	9
10	8.328	8.322	8.317	8.311	8.305	8.299	8.293	8.287	8.282	8.276
	1.0000	.9993	.9986	.9979	.9972	.9965	.9958	.951	.9944	.9937
11	8.270	8.264	8.258	8.252	8.246	8.241	8.235	8.229	8.223	8.218
	.9930	.9923	.9916	.9909	.9902	.9895	.9888	.9881	.9874	.9868
12	8.212	8.206	8.201	8.195	8.189	8.183	8.178	8.172	8.166	8.161
	.9861	.9854	.9847	.9840	.9833	.9826	.9820	.9813	.9806	.9799
13	8.155	8.150	8.144	8.138	8.132	8.127	8.122	8.116	8.110	8.105
	.9792	.9786	.9779	.9772	.9765	.9759	.9752	.9745	.9738	.9732
14	8.099	8.093	8.088	8.082	8.076	8.071	8.066	8.061	8.055	8.049
	.9725	.9718	.9712	.9705	.9698	.9692	.9685	.9679	.9672	.9665
15	8.044	8.038	8.033	8.027	8.021	8.016	8.011	8.006	8.000	7.995
	.9659	.9652	.9646	.9639	.9632	.9626	.9619	.9613	.9606	.9600
16	7.989	7.984	7.978	7.973	7.967	7.962	7.956	7.951	7.946	7.940
	.9593	.9587	.9580	.9574	.9567	.9561	.9554	.9548	.9541	.9535
17	7.935	7.930	7.925	7.919	7.914	7.909	7.903	7.898	7.893	7.887
	.9529	.9522	.9516	.9509	.9503	.9497	.9490	.9484	.9478	.9471
18	7.882	7.877	7.871	7.866	7.861	7.856	7.851	7.846	7.841	7.835
	.9465	.9459	.9452	.9446	.9440	.9433	.9427	.9421	.9415	.9408
19	7.830	7.825	7.820	7.814	7.809	7.804	7.799	7.793	7.788	7.783
	.9402	.9396	.9390	.9383	.9377	.9371	.9365	.9358	.9352	.9346
20	7.778	7.773	7.768	7.762	7.757	7.752	7.747	7.742	7.737	7.732
	.9340	.9334	.9328	.9321	.9315	.9309	.9303	.9297	.9291	.9285
21	7.727	7.722	7.717	7.711	7.706	7.701	7.696	7.691	7.686	7.681
	.9279	.9273	.9267	.9260	.9254	.9248	.9242	.9236	.9230	.9224
22	7.676	7.671	7.666	7.661	7.656	7.651	7.646	7.641	7.636	7.632
	.9218	.9212	.9206	.9200	.9194	.9188	.9182	.9176	.9170	.9165
23	7.627	7.622	7.617	7.612	7.607	7.602	7.597	7.592	7.587	7.583
	.9159	.9153	.9147	.9141	.9135	.9129	.9123	.9117	.9111	.9106
24	7.578	7.573	7.568	7.563	7.558	7.554	7.549	7.544	7.539	7.534
	.9100	.9094	.9088	.9082	.9076	.9071	.9065	.9059	.9053	.9047
25	7.529	7.524	7.519	7.514	7.509	7.505	7.500	7.495	7.491	7.486
	.9042	.9036	.9030	.9024	.9018	.9013	.9007	.9001	.8996	.8990
26	7.481	7.476	7.472	7.467	7.462	7.458	7.453	7.448	7.443	7.438
	.8984	.8978	.8973	.8967	.8961	.8956	.8950	.8944	.8939	.8933
27	7.434	7.429	7.424	7.420	7.415	7.410	7.406	7.401	7.397	7.392
	.8927	.8922	.8916	.8911	.8905	.8899	.8894	.8888	.8883	.8877
28	7.387	7.383	7.378	7.373	7.368	7.364	7.360	7.355	7.350	7.346
	.8871	.8866	.8860	.8855	.8849	.8844	.8838	.8833	.8827	.8822
29	7.341	7.337	7.332	7.328	7.323	7.318	7.314	7.309	7.305	7.300
	.8816	.8811	.8805	.8800	.8794	.8789	.8783	.8778	.8772	.8767
30	7.296	7.291	7.287	7.282	7.278	7.273	7.268	7.264	7.259	7.255
	.8762	.8756	.8751	.8745	.8740	.8735	.8729	.8724	.8718	.8713
31	7.251	7.246	7.242	7.238	7.233	7.228	7.224	7.219	7.215	7.211
	.8708	.8702	.8679	.8692	.8686	.8681	.8676	.8670	.8665	.8660
32	7.206	7.202	7.198	7.193	7.188	7.184	7.180	7.176	7.171	7.167
	.8654	.8649	.8644	.8639	.8633	.8628	.8623	.8618	.8612	.8607
33	7.163	7.158	7.153	7.149	7.145	7.141	7.137	7.132	7.128	7.123
	.8602	.8597	.8591	.8586	.8581	.8576	.8571	.8565	.8560	.8555
34	7.119	7.115	7.111	7.106	7.102	7.098	7.093	7.089	7.085	7.081
	.8550	.8545	.8540	.8534	.8529	.8524	.8519	.8514	.8509	.8504
35	7.076	7.072	7.067	7.063	7.059	7.055	7.051	7.047	7.042	7.038
	.8498	.8493	.8488	.8483	.8478	.8473	.8468	.8463	.8458	.8453

Pounds per gallon and specific gravities corresponding to degrees API at 60°F

(Continued)

Deg API	TENTHS OF DEGREES									
	0	1	2	3	4	5	6	7	8	9
36	7.034	7.030	7.026	7.022	7.018	7.013	7.009	7.005	7.001	6.997
	.8448	.8443	.8438	.8433	.8428	.8423	.8418	.8412	.8408	.8403
37	6.993	6.989	6.985	6.980	6.976	6.972	6.968	6.964	6.960	6.955
	.8398	.8393	.8388	.8383	.8378	.8373	.8368	.8363	.8358	.8353
38	6.951	6.947	6.943	6.939	6.935	6.930	6.926	6.922	6.918	6.914
	.8348	.8343	.8338	.8333	.8328	.8324	.8319	.8314	.8309	.8304
39	6.910	6.906	6.902	6.898	6.894	6.890	6.886	6.882	6.878	6.874
	.8299	.8294	.8289	.8285	.8280	.8275	.8270	.8265	.8260	.8256
40	6.870	6.866	6.862	6.858	6.854	6.850	6.846	6.842	6.838	6.834
	.8251	.8246	.8241	.8236	.8232	.8227	.8222	.8217	.8212	.8208
41	6.830	6.826	6.822	6.818	6.814	6.810	6.806	6.802	6.798	6.794
	.8203	.8198	.8193	.8189	.8184	.8178	.8174	.8170	.8165	.8160
42	6.790	6.786	6.782	6.779	6.775	6.771	6.767	6.763	6.759	6.756
	.8155	.8151	.8146	.8142	.8137	.8132	.8128	.8123	.8118	.8114
43	6.752	6.748	6.744	6.740	6.736	6.732	.728	6.724	6.720	6.716
	.8109	.8104	.8100	.8095	.8090	.8086	6.8081	.8076	.8072	.8067
44	6.713	6.709	6.705	6.701	6.697	6.694	6.690	6.686	6.682	6.679
	.8063	.8058	.8054	.8049	.8044	.8040	.8035	.8031	.8026	.8022
45	6.675	6.671	6.667	6.663	6.660	6.656	6.652	6.648	6.645	6.641
	.8017	.8012	.8008	.8003	.7999	.7994	.7990	.7985	.7981	.7976
46	6.637	6.633	6.630	6.626	6.622	6.618	6.615	6.611	6.607	6.604
	.7972	.7967	.7963	.7958	.7954	.7949	.7945	.7941	.7936	.7932
47	6.600	6.596	6.592	6.589	6.585	6.582	6.578	6.574	6.571	6.567
	.7927	.7923	.7918	.7914	.7909	.7905	.7901	.7896	.7892	.7887
48	6.563	6.560	6.556	6.552	6.548	6.545	6.541	6.537	6.534	6.530
	.7883	.7879	.7874	.7870	.7865	.7861	.7857	.7852	.7848	.7844
49	6.526	6 523	6.520	6.516	6.512	6.509	6.505	6.501	6.498	6.494
	.7839	.7835	.7831	.7826	.7822	.7818	.7813	.7809	.7805	.7800
50	6.490	6.487	6.484	6.480	6.476	6.473	6.469	6.466	6.462	6.459
	.7796	.7792	.7788	.7783	.7779	.7775	.7770	.7766	.7762	.7758
51	6.455	6.451	6.448	6.445	6.441	6.437	6.434	6.430	6.427	6.423
	.7753	.7749	.7745	.7741	.7736	.7732	.7728	.7724	.7720	.7715
52	6.420	6.416	6.413	6.410	6.406	6.402	6.399	6.396	6.392	6.389
	.7711	.7707	.7703	.7699	.7694	.7690	.7686	.7682	.7678	.7674
53	6.385	6.381	6.378	6.375	6.371	6.368	6.365	6.360	6.357	6.354
	.7669	.7665	.7661	.7657	.7653	.7649	.7645	.7640	.7636	.7632
54	6.350	6.347	6.344	6.340	6.337	6.334	6.330	6.326	6.323	6.320
	.7628	.7624	.7620	.7616	.7612	.7608	.7603	.7599	.7595	.7591
55	6.316	6.313	6.310	6.306	6.303	6.300	6.296	6.293	6.290	6.287
	.7587	.7583	.7579	.7575	.7571	.7567	.7563	.7559	.7555	.7551
56	6.283	6.280	6.276	6.273	6.270	6.266	6.263	6.259	6.256	6.253
	.7547	.7543	.7539	.7535	.7531	.7527	.7523	.7519	.7515	.7511
57	6.249	6.246	6.243	6.240	6.236	6.233	6.229	6.226	6.223	6.219
	.7507	.7503	.7499	.7495	.7491	.7487	.7483	.7479	.7475	.7471
58	6.216	6.213	6.209	6.206	6.203	6.199	6.196	6.193	6.190	6.187
	.7467	.7463	.7459	.7455	.7451	.7447	.7443	.7440	.7436	.7432
59	6.184	6.180	6.177	6.174	6.170	6.167	6.164	6.161	6.158	6.154
	.7428	.7424	.7420	.7416	.7412	.7408	.7405	.7401	.7397	.7393
60	6.151	6.148	6.144	6.141	6.138	6.135	6.132	6.129	6.125	6.122
	.7389	.7385	.7381	.7377	.7374	.7370	.7366	.7362	.7358	.7354

Pounds per gallon and specific gravities corresponding to degrees A P I at 60°F

(continued)

Deg API	TENTHS OF DEGREES									
	0	1	2	3	4	5	6	7	8	9
61	6.119	6.116	6.113	6.109	6.106	6.103	6.100	6.097	6.094	6.090
	.7351	.7347	.7343	.7339	7335	.7332	.7328	.7324	.7320	.7316
62	6.087	6.084	6.081	6.078	6.075	6.072	6.068	6.065	6.062	6.059
	.7313	.7309	.7305	.7301	.7298	.7294	.7290	.7286	.7283	.7279
63	6.056	6.053	6.050	6.047	6.044	6.040	6.037	6.034	6.031	6.028
	.7275	.7271	.7268	.7264	.7260	.7256	.7253	.7249	.7245	.7242
64	6.025	6.022	6.019	6.016	6.013	6.010	6.007	6.004	6.000	5.997
	.7238	.7234	.7230	.7227	.7223	.7219	.7216	.7212	.7208	.7205
65	5.994	5.991	5.988	5.985	5.982	5.979	5.976	5.973	5.970	5.967
	.7201	.7197	.7194	.7190	.7186	.7183	.7179	.7175	.7172	.7168
66	5.964	5.961	5.958	5.955	5.952	5.949	5.946	5.943	5.940	5.937
	.7165	.7161	.7157	.7154	.7150	.7146	.7143	.7139	.7136	.7132
67	5.934	5.931	5.928	5.925	5.922	5.919	5.916	5.913	5.910	5.907
	.7128	.7125	.7121	.7118	.7114	.7111	.7107	.7103	.7100	.7096
68	5.904	5.901	5.898	5.895	5.892	5.889	5.886	5.883	5.880	5.877
	.7093	.7089	.7086	.7082	.7079	.7075	.7071	.7068	.7064	.7061
69	5.874	5.871	5.868	5.866	5.863	5.860	5.857	5.854	5.851	5.848
	.7057	.7054	.7050	.7047	.7043	.7040	.7036	.7033	.7029	.7026
70	5.845	5.842	5.839	5.836	5.833	5.831	5.828	5.825	5.823	5.820
	.7022	.7019	.7015	.7012	.7008	.7005	.7001	.6998	.6995	.6991
71	5.817	5.814	5.811	5.808	5.805	5.802	5.799	5.796	5.793	5.791
	.6988	.6984	.6981	.6977	.6974	.6970	.6967	.6964	.6960	.6957
72	5.788	5.785	5.782	5.779	5.776	5.773	5.771	5.768	5.765	5.762
	.6952	.6950	.6946	.6943	.6940	.6936	.6933	.6929	.6926	.6923
73	5.759	5.757	5.754	5.751	5.748	5.745	5.743	5.740	5.737	5.734
	.6919	.6916	.6913	.6909	.6906	.6902	.6899	.6896	.6892	.6889
74	5.731	5.728	5.726	5.723	5.720	5.718	5.715	5.712	5.709	5.706
	.6886	.6882	.6879	.6876	.6872	.6869	.6866	.6862	.6859	.6856
75	5.703	5.701	5.698	5.695	5.693	5.690	5.687	5.685	5.682	5.679
	.6852	.6849	.6846	.6842	.6839	.6836	.6832	.6829	.6826	.6823
76	5.676	5.673	5.671	5.668	5.665	5.662	5.660	5.657	5.654	5.652
	.6819	.6816	.6813	.6809	.6806	.6803	.6800	.6796	.6793	.6790
77	5.649	5.646	5.643	5.641	5.638	5.635	5.632	5.630	5.627	5.624
	.6787	.6783	.6780	.6777	.6774	.6770	.6767	.6764	.6761	.6757
78	5.622	5.619	5.617	5.614	5.611	5.608	5.606	5.603	5.600	5.598
	.6754	.6751	.6748	.6745	.6741	.6738	.6735	.6732	.6728	.6725
79	5.595	5.592	5.590	5.587	5.584	5.582	5.579	5.577	5.574	5.571
	.6722	.6719	.6716	.6713	.6709	.6706	.6703	.6700	.6697	.6693
80	5.568	5.566	5.563	5.561	5.558	5.556	5.553	5.550	5.548	5.545
	.6690	.6687	.6684	.6681	.6678	.6675	.6671	.6668	.6665	.6662
81	5.542	5.540	5.537	5.534	5.532	5.529	5.526	5.524	5.522	5.519
	.6659	.6656	.6653	.6649	.6646	.6643	.6640	.6637	.6634	.6631
82	5.516	5.514	5.511	5.508	5.506	5.503	5.501	5.498	5.496	5.493
	.6628	.6625	.6621	.6618	.6615	.6612	.6609	.6606	.6603	.6600
83	5.491	5.489	5.486	5.483	5.480	5.477	5.475	5.472	5.470	5.467
	.6597	.6594	.6591	.6588	.6584	.6581	.6578	.6575	.6572	.6569
84	5.465	5.462	5.460	5.458	5.455	5.453	5.450	5.448	5.445	5.443
	.6566	.6563	.6560	.6557	.6554	.6551	.6548	.6545	.6542	.6539
85	5.440	5.437	5.435	5.432	5.430	5.427	5.425	5.422	5.420	5.417
	.6536	.6533	.6530	.6527	.6524	.6521	.6518	.6515	.6512	.6509

Pounds per gallon and specific gravities corresponding to degrees A P I at 60°F

(Continued)

Deg	TENTHS OF DEGREES									
	0	1	2	3	4	5	6	7	8	9
86	5.415 .6506	5.412 .6503	5.410 .6500	5.407 .6497	5.405 .6494	5.402 .6491	5.400 .6488	5.397 .6485	5.395 .6482	5.392 .6479
87	5.390 .6476	5.387 .6473	5.385 .6470	5.382 .6467	5.380 .6464	5.377 .6461	5.375 .6458	5.372 .6455	5.370 .6452	5.367 .6449
88	5.365 .6446	5.363 .6444	5.361 .6441	5.358 .6438	5.356 .6435	5.353 .6432	5.351 .6429	5.348 .6426	5.346 .6423	5.343 .6420
89	5.341 .6417	5.338 .6414	5.336 .6411	5.334 .6409	5.331 .6406	5.329 .6403	5.326 .6400	5.324 .6397	5.321 .6394	5.319 .6391
90	5.316 .6388	5.314 .6385	5.312 .6382	5.310 .6380	5.307 .6377	5.305 .6374	5.302 .6371	5.300 .6368	5.297 .6365	5.295 .6362
91	5.293 .6360	5.291 .6357	5.288 .6354	5.286 .6351	5.283 .6348	5.281 .6345	5.278 .6342	5.276 .6340	5.274 .6337	5.271 .6334
92	5.269 .6331	5.266 .6328	5.264 .6325	5.262 .6323	5.260 .6320	5.257 .6317	5.254 .6314	5.252 .6311	5.250 .6309	5.248 .6306
93	5.245 .6303	5.243 .6300	5.241 .6297	5.238 .6294	5.236 .6292	5.234 .6289	5.232 .6286	5.229 .6283	5.227 .6281	5.225 .6278
94	5.222 .6275	5.220 .6272	5.217 .6269	5.215 .6267	5.213 .6264	5.211 .6261	5.208 .6258	5.206 .6256	5.204 .6253	5.201 .6250
95	5.199 .6247	5.196 .6244	5.194 .6242	5.192 .6239	5.190 .6236	5.187 .6233	5.185 .6231	5.183 .6228	5.180 .6225	5.179 .6223
96	5.176 .6220	5.174 .6217	.5172 .6214	5.170 .6212	5.167 .6209	5.164 .6206	5.162 .6203	5.160 .6201	5.158 .6198	5.156 .6195
97	5.154 .6193	5.151 .6190	5.149 .6187	5.146 .6184	5.144 .6182	5.142 .6179	5.140 .6176	5.138 .6174	5.136 .6171	5.133 .6168
98	5.131 .6166	5.129 .6163	5.126 .6160	5.124 .6158	5.122 .6155	5.120 .6152	5.118 .6150	5.116 .6147	5.113 .6144	5.111 .6141
99	5.109 .6139	5.107 .6136	5.104 .6134	5.102 .6131	5.100 .6128	5.098 .6126	5.096 .6123	5.093 .6120	5.091 .6118	5.089 .6115
100	5.086 .6112	5.09 .6110	5.09 .6107	5.08 .6104	5.08 .6102	5.08 .6099	5.08 .6097	5.07 .6094	5.07 .6091	5.07 .6089
101	5.07 .6086	5.07 .6083	5.06 .6081	5.06 .6078	5.06 .6076	5.06 .6073	5.05 .6070	5.05 .6068	5.05 .6065	5.05 .6063
102	5.05 .6060	5.04 .6058	5.04 .6055	5.04 .6052	5.04 .6050	5.04 .6047	5.03 .6044	5.03 .6042	5.03 .6039	5.03 .6037
103	5.02 .6034	5.02 .6032	5.02 .6029	5.02 .6026	5.02 .6024	5.01 .6021	5.01 .6019	5.01 .6016	5.01 .6014	5.01 .6011
104	5.00 .6008	5.00 .6006	5.00 .6003	5.00 .6001	4.99 .5998	4.99 .5996	4.99 .5993	4.99 .5591	4.99 .5988	4.98 .5986
105	4.98 .5983	4.98 .5981	4.98 .5978	4.98 .5976	4.97 .5973	4.97 .5970	4.97 .5968	4.97 .5965	4.97 .5963	4.96 .5960
106	4.96 .5958	4.96 .5955	4.96 .5953	4.95 .5950	4.95 .5948	4.95 .5945	4.95 .5943	4.95 .5940	4.94 .5938	4.94 .5935
107	4.94 .5933	4.94 .5930	4.94 .5928	4.93 .5925	4.93 .5923	4.93 .5921	4.93 .5918	4.93 .5916	4.92 .5913	4.92 .5911
108	4.92 .5908	4.92 .5906	4.92 .5903	4.91 .5901	4.91 .5898	4.91 .5896	4.91 .5893	4.91 .5891	4.90 .5888	4.90 .5886
109	4.90 .5884	4.90 .5881	4.90 .5879	4.89 .5876	4.89 .5874	4.89 .5871	4.89 .5869	4.89 .5867	4.88 .5864	4.88 .5862
110	4.88 .5859	4.88 .5857	4.87 .5854	4.87 .5852	4.87 .5850	4.87 .5847	4.87 .5845	4.86 .5842	4.86 .5840	4.86 .5837
111	4.86 .5835	4.86 .5833	4.85 .5830	4.85 .5828	4.85 .5825	4.85 .5823	4.85 .5821	4.84 .5818	4.84 .5816	4.84 .5813
112	4.84 .5811	4.84 .5909	4.83 .5806	4.83 .5804	4.83 .5802	4.83 .5799	4.83 .5797	4.82 .5794	4.82 .5792	4.82 .5790

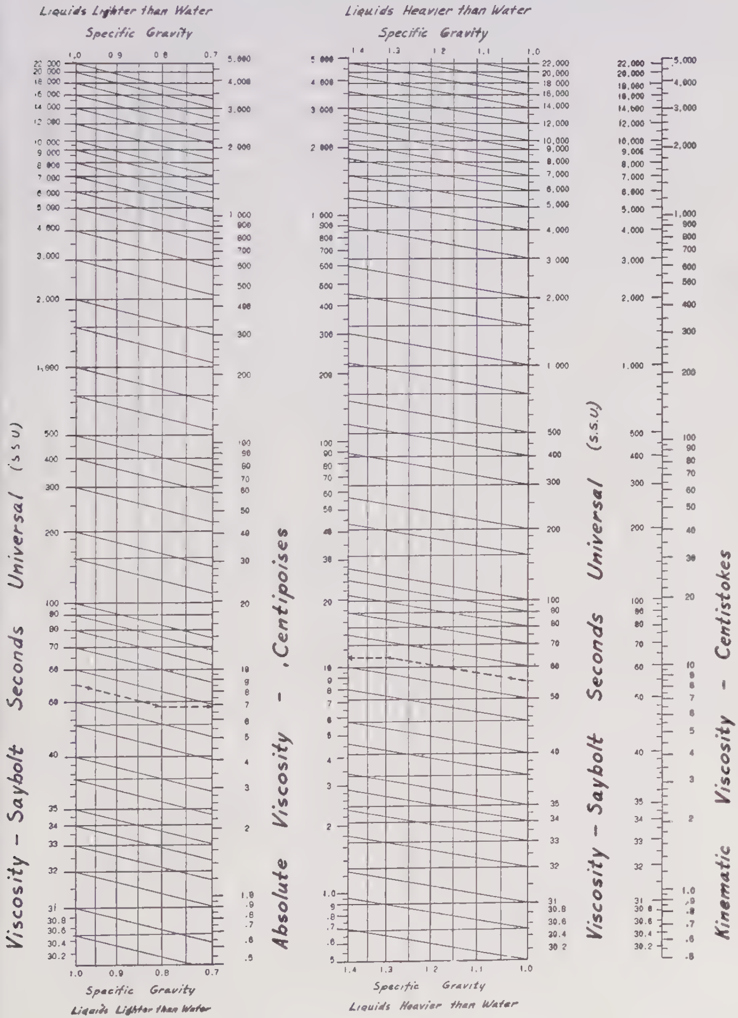
Pounds per gallon and specific gravities corresponding to degrees A P I at 60°F

(Continued)

Deg API	TENTHS OF DEGREES 0	1	2	3	4	5	6	7	8	9
113	4.82 .5787	4.82 .5785	4.82 .5783	4.81 .5780	4.81 .5778	4.81 .5776	4.81 .5773	4.81 .5771	4.80 .5768	4.80 .5766
114	4.80 .5764	4.80 .5761	4.80 .5759	4.79 .5757	4.79 .5754	4.79 .5752	4.79 .5750	4.79 .5747	4.78 .5745	4.78 .5743
115	4.78 .5740	4.78 .5738	4.78 .5736	4.77 .5733	4.77 .5731	4.77 .5729	4.77 .5726	4.77 .5724	4.76 .5722	4.76 .5719
116	4.76 .5717	4.76 .5715	4.76 .5713	4.76 .5710	4.75 .5708	4.75 .5706	4.75 .5703	4.75 .5701	4.75 .5699	4.74 .5696
117	4.74 .5694	4.74 .5692	4.74 .5690	4.74 .5687	4.73 .5685	4.73 .5683	4.73 .5680	4.73 .5678	4.73 .5676	4.73 .5674
118	4.72 .5671	4.72 .5669	4.72 .5667	4.72 .5665	4.72 .5662	4.71 .5660	4.71 .5658	4.71 .5655	4.71 .5653	4.71 .5651
119	4.70 .5649	4.70 .5646	4.70 .5644	4.70 .5642	4.70 .5640	4.69 .5637	4.69 .5635	4.69 .5633	4.69 .5631	4.69 .5628
120	4.69 .5626	4.68 .5624	4.68 .5622	4.68 .5620	4.68 .5617	4.68 .5615	4.67 .5613	4.67 .5611	4.67 .5608	4.67 .5606
121	4.67 .5604	4.67 .5602	4.66 .5600	4.66 .5597	4.66 .5595	4.66 .5593	4.66 .5591	4.65 .5588	4.65 .5586	4.65 .5584
122	4.65 .5582	4.65 .5580	4.64 .5577	4.64 .5575	4.64 .5573	4.64 .5571	4.64 .5569	4.64 .5566	4.63 .5564	4.63 .5562
123	4.63 .5560	4.63 .5558	4.63 .5556	4.62 .5553	4.62 .5551	4.62 .5549	4.62 .5547	4.62 .5545	4.62 .5542	4.61 .5540
124	4.61 .5538	4.61 .5536	4.61 .5534	4.61 .5532	4.61 .5530	4.60 .5527	4.60 .5525	4.60 .5523	4.60 .5521	4.60 .5519
125	4.59 .5517	4.59 .5514	4.59 .5512	4.59 .5510	4.59 .5508	4.59 .5506	4.58 .5504	4.58 .5502	4.58 .5499	4.58 .5497
126	4.58 .5495	4.57 .5493	4.57 .5491	4.57 .5489	4.57 .5487	4.57 .5484	4.57 .5482	4.56 .5480	4.56 .5478	4.56 .5476
127	4.56 .5474	4.56 .5472	4.56 .5470	4.55 .5468	4.55 .5465	4.55 .5463	4.55 .5461	4.55 .5459	4.54 .5457	4.54 .5455
128	4.54 .5453	4.54 .5451	4.54 .5449	4.54 .5446	4.53 .5444	4.53 .5442	4.53 .5440	4.53 .5438	4.53 .5436	4.53 .5434
129	4.52 .5432	4.52 .5430	4.52 .5428	4.52 .5426	4.52 .5424	4.51 .5421	4.51 .5419	4.51 .5417	4.51 .5415	4.51 .5413
130	4.51 .5411	4.50 .5409	4.50 .5407	4.50 .5405	4.50 .5403	4.50 .5401	4.50 .5399	4.49 .5397	4.49 .5395	4.49 .5393
131	4.49 .5390	4.49 .5388	4.49 .5386	4.48 .5384	4.48 .5382	4.48 .5380	4.48 .5378	4.48 .5376	4.48 .5374	4.47 .5372
132	4.47 .5370	4.47 .5368	4.47 .5366	4.47 .5364	4.47 .5362	4.46 .5360	4.46 .5358	4.46 .5356	4.46 .5354	4.46 .5352
133	4.46 .5350	4.45 .5348	4.45 .5346	4.45 .5344	4.45 .5342	4.45 .5340	4.45 .5338	4.44 .5336	4.44 .5334	4.44 .5332
134	4.44 .5330	4.44 .5328	4.44 .5326	4.43 .5324	4.43 .5322	4.43 .5320	4.43 .5318	4.43 .5316	4.43 .5314	4.42 .5312
135	4.42 .5310	4.42 .5308	4.42 .5306	4.42 .5304	4.42 .5302	4.41 .5300	4.41 .5298	4.41 .5296	4.41 .5294	4.41 .5292
136	4.41 .5290	4.40 .5288	4.40 .5286	4.40 .5284	4.40 .5282	4.40 .5280	4.40 .5278	4.39 .5276	4.39 .5274	4.39 .5272
137	4.39 .5270	4.39 .5268	4.39 .5266	4.38 .5264	4.38 .5262	4.38 .5260	4.38 .5258	4.38 .5256	4.38 .5254	4.37 .5252
138	4.37 .5250	4.37 .5249	4.37 .5247	4.37 .5245	4.37 .5243	4.36 .5241	4.36 .5239	4.36 .5237	4.36 .5235	4.36 .5233
139	4.36 .5231	4.35 .5229	4.35 .5227	4.35 .5225	4.35 .5223	4.35 .5221	4.35 .5219	4.35 .5218	4.34 .5216	4.34 .5214

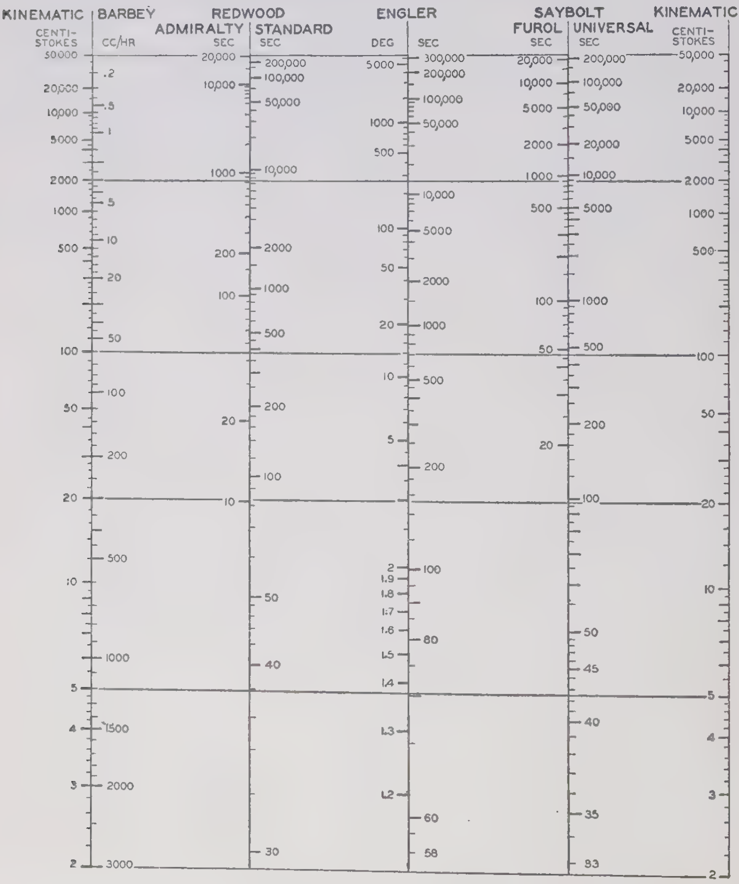
Values from 10.0 to 100.0 API from tables published by American Petroleum Institute
Values above 100 0 API calculated by Ingersoll-Rand Co.

Conversion S.S.U. Viscosity to Absolute and Kinematic Viscosity



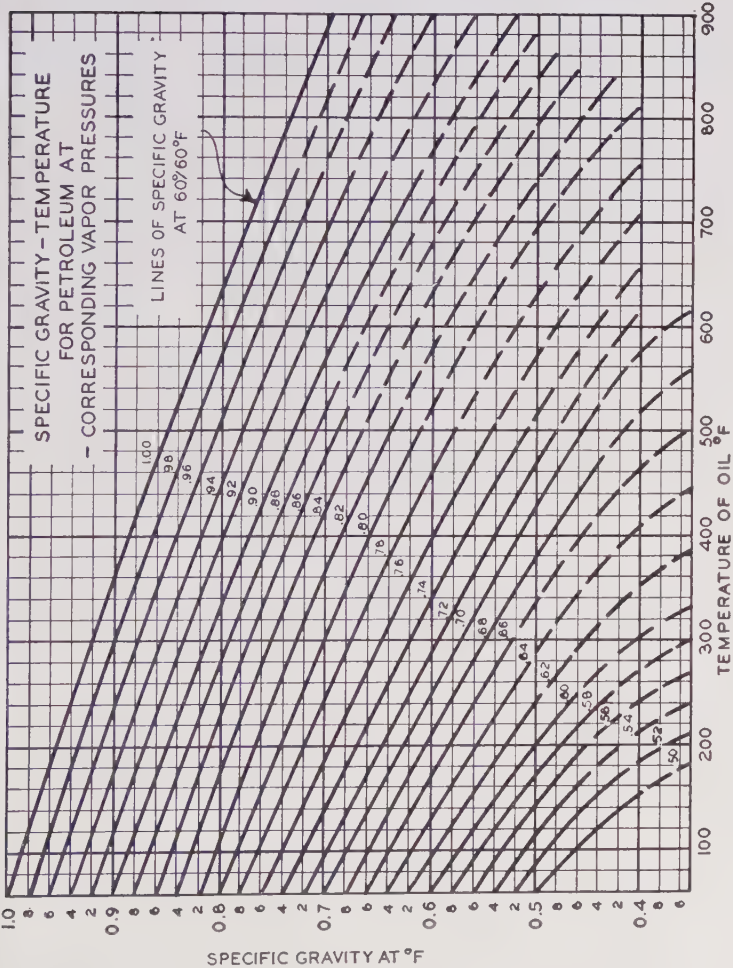
3

Viscosimeter Conversion Chart



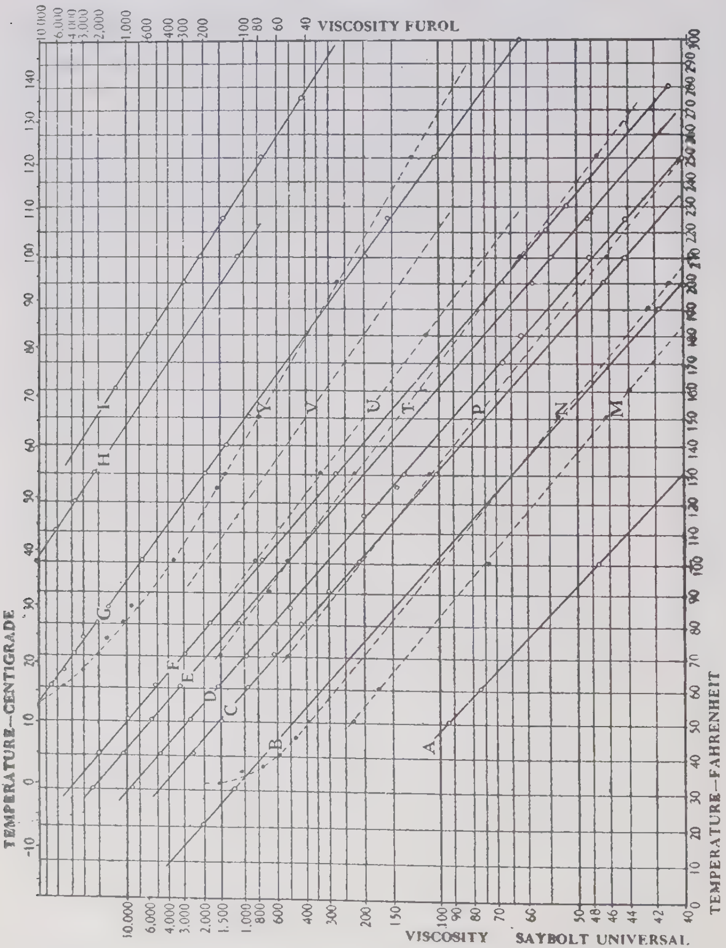
Read horizontally across chart.

Specific Gravity and Temperature Relations of Petroleum Oils (Approximate)



Courtesy of M. W. Kellogg Co.

Viscosity—Temperature Relations of Petroleum Oils

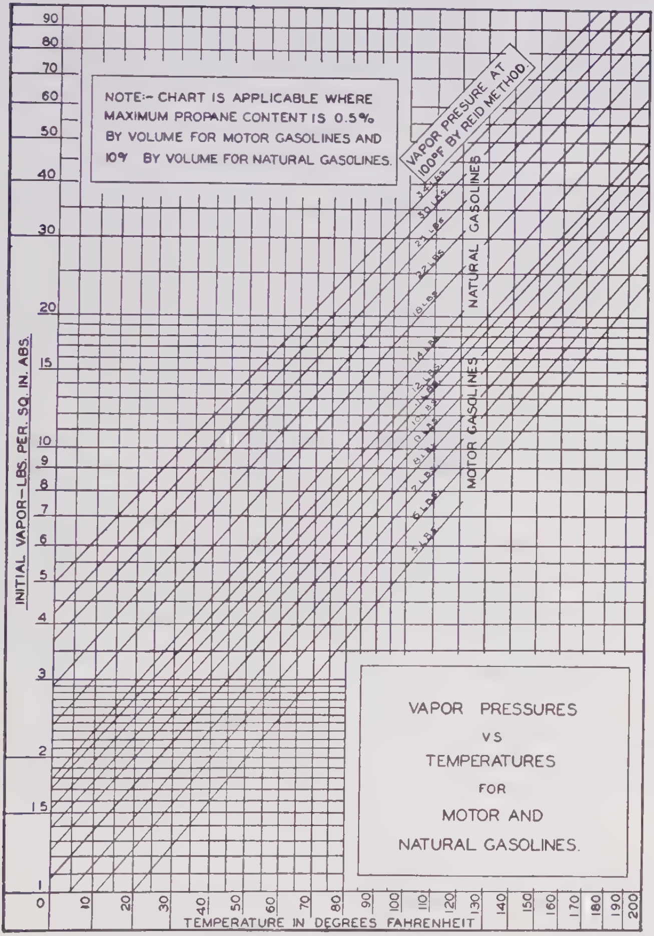


This chart may be used to determine the viscosity of an oil at any temperature provided its viscosity at two temperatures is known.

The lines on this chart show viscosities of representative oils.

Note: This chart is similar to ASTM tentative standard D341-32T which has a somewhat wider viscosity and temperature range.

Courtesy of The Texas Co.



Courtesy-Chicago Bridge & Iron Works

To determine the gage working pressure of a vessel to store any natural gasoline:

1. Determine the maximum liquid surface temperature reached or likely to be reached by the liquid during the period of storage.
2. The vertical temperature line intersects the Reid vapor pressure line for the liquid being considered at a definite point.
3. From the curve determine the initial vapor pressure in pounds absolute at the left hand side horizontally from the intersection mentioned in "2".
4. From the initial vapor pressure in pounds absolute substract 14.7. The result is the gage working pressure of the vessel required to store that liquid, without evaporation loss.

Friction of Fluids in Pipe

The loss of head due to the friction of fluids flowing in pipe can be determined for any liquid or gas by means of the Fanning equation derived from Bernoulli's theorem. This equation may be written thus:

$$h = \frac{fLv^2}{2gD}$$

The friction factor, f, in this equation has been determined experimentally in relation to a dimensionless ratio known as Reynolds number. Reynolds number is written: $R = \frac{Dvp}{u}$. A curve giving values of the friction factor, f is given on page 94 This curve may be used in connection with the formula above or those below, which are in units widely used by engineers.

For liquids

$$R = \frac{Dvp}{u} = \frac{3162q}{dk} = \frac{2214B}{dk}$$

$$h = \frac{fLv^2}{2gD} = \frac{.03112fLq^2}{d^5} = \frac{.0153fLB^2}{d^5}$$

For gases

$$R = \frac{Dvp}{u} = \frac{22{,}735Qp}{dz} = \frac{378.9q_1p}{dz} = \frac{6.32W}{dz}$$

$$P = \frac{fLv^2p}{24gd} = \frac{43.53fLQ^2p}{d^5} = \frac{.01209fLq_1{}^2p}{d^5} = \frac{.00000336fLW^2}{pd^5}$$

Below a Reynolds number of about 2100, the character of flow changes from the usual turbulent type to viscous or streamline flow. Experiments have shown that the surface of the pipe has no influence on the friction factor when flow is of the streamline type. Therefore, for all kinds of pipe when the Reynolds number is less than 2100 a value of $f = \frac{64}{R}$ should be used.

Symbols used in formulae above are as follows:

B = flow of liquid, barrels (42 gal) per hr

d = inside dia of circular pipe, inches

D = inside dia of circular pipe, feet

f = friction factor, dimensionless

g = acceleration of gravity, ft per sec^2 (taken as 32.174ft per sec^2 in making conversions)

h = head loss due to friction, ft (equivalent to a column of liquid of a height in feet giving the pressure necessary to overcome the friction loss)

k = kinematic viscosity, centistokes $= \frac{z}{s}$

L = length of pipe line, including equivalent length for loss through fittings, ft. In long lines over about 4000 ft where loss due to fittings is a small portion of the total they can usually be neglected

P = loss due to friction, lb per sq in

p = density at temp and press at which fluid is flowing, lb per ft^3

q = flow of liquid, gal per min

q_1 = flow of gas, cu ft per min at temp and press of flow conditions

Q = flow of gas, cu ft per sec at temp and press of flow conditions

R = Reynolds number, dimensionless

s = density gr per cu cm = sp gr referred to water at 39.2F as 1

u = absolute viscosity, lb per ft sec $= \frac{z}{1488}$

v = velocity of flow, ft per sec

W = flow of gas, lb per hr

z = absolute viscosity, centipoises = 1488u

It will be noted that these data apply to any liquid, whereas the Williams and Hazen tables apply only to water at about 60F or to other liquids having a kinematic viscosity of about 1.1 centistokes (31.5 SSU).

The tables on pages 96 to 123 may be used for any true liquid but not for suspensions or plastics.

These are calculated from curves appearing in the Standards of the Hydraulic Institute. The curves on pages 94 and 95 are reproduced from the Institute curves.

While it is not entirely rational to apply multiplication factors to the figures given in these tables for obtaining friction losses in other types of pipe, it may often be convenient for approximate results.

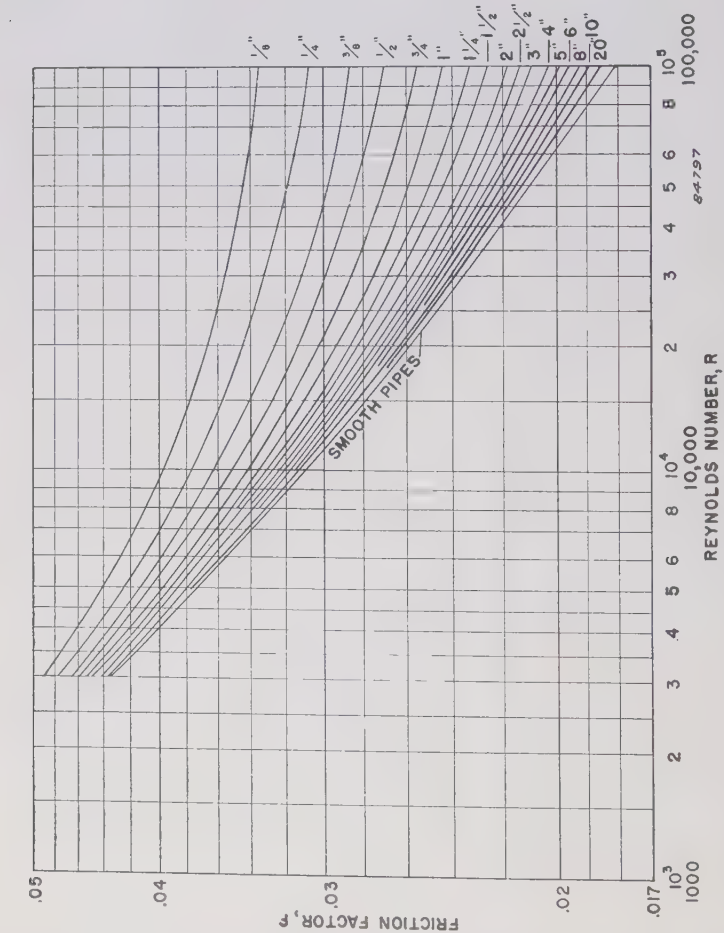
For this reason a table of multipliers is given below. For more accurate results the formula above, together with the appropriate friction factor from the curve on page 94 should be used.

Type of Pipe	Approx equivalent Williams and Hazen constant	Multiplier for approx correction of tables pg 96 to 123 (Do not apply to figures in italics)
Very best smooth pipe	150	.9
Smooth, clean, steel, copper, brass or cement-asbestos	140	1.0
Straight galvanized iron	135	1.05
Best cast iron or cement	130	1.1
Average cast iron or cement	125	1.2
Average wrought iron; 5 yr old cast iron	120	1.27
11 yr old cast iron, spiral riveted flow with lap	110	1.5
17 yr old cast iron, spiral riveted flow against lap	100	1.8

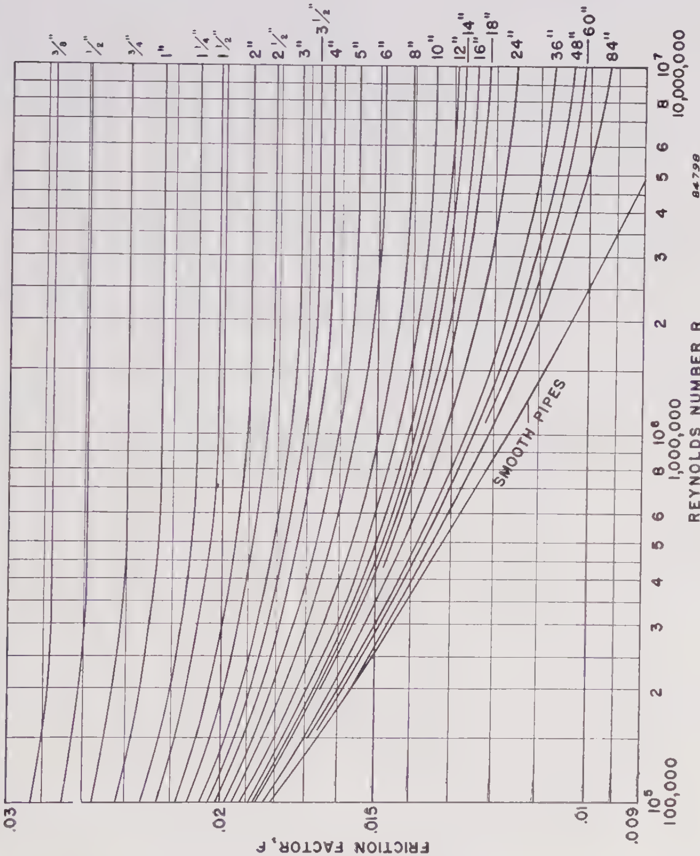
FRICTION OF FLUIDS IN PIPE

Values of friction factor, f, for flow formula page 92

for flow formula page 92



FRICTION OF FLUIDS IN PIPE
Values of friction factor, f, for flow formula page 92



"Reprinted from the Tentative Standards of Hydraulic Institute, Pipe Friction, Copyright 1948, by Hydraulic Institute, 122 East 42nd Street, New York 17, N. Y."

Friction Losses In Pipe; 1 Inch (1.049″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
US gal per min	Bbl per hr (42 gal)	0.6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity									
			31.5	33	35	40	50	60	70	80	100
.5	.71	.29	*.28*	*.55*	*.70*	*1.12*	*1.93*	*2.68*	*3.41*	*4.08*	*5.35*
1	1.4	.96	1.13	*1.09*	*1.41*	*2.24*	*3.86*	*5.36*	*6.82*	*8.16*	*10.7*
2	2.9	3.23	3.72	4.41	4.80	*4.48*	*7.72*	*10.7*	*13.6*	*16.3*	*21.4*
3	4.3	6.84	7.63	9.04	9.48	10.8	*11.6*	*16.1*	*20.5*	*24.5*	*32.1*
4	5.7	11.4	12.2	14.9	15.9	17.6	*15.4*	*21.5*	*27.3*	*32.6*	*42.8*
5	7.1	17.2	19.2	22.1	23.4	26.3	*19.3*	*26.8*	*34.1*	*40.8*	*53.5*
6	8.6	24.2	26.8	30.5	32.1	36.8	41.3	*32.2*	*40.9*	*49.0*	*64.2*
7	10.0	32.3	35.4	40.8	42.6	47.4	53.8	*37.5*	*47.7*	*57.2*	*74.9*
8	11.4	41.6	45.5	51.1	54.3	59.9	68.2	75.3	*54.5*	*65.2*	*85.6*
9	12.9	51.8	56.2	63.5	66.3	73.4	84.9	91.7	*61.4*	*73.4*	*96.3*
10	14.3	62.7	68.1	76.2	80.1	88.2	101	111	115	*81.6*	*107*
12	17.1	89.3	95.3	106	111	122	142	151	162	167	*129*
14	20.0	120	129	140	147	160	185	198	212	221	*150*
16	22.8	155	164	181	188	205	234	257	268	279	295
18	25.7	194	202	224	233	254	286	305	326	341	365
20	28.6	237	250	272	281	308	342	372	394	405	437
25	35.7	368	383	410	429	464	501	551	583	599	651
30	42.9	523	545	582	600	640	712	759	803	842	904
35	50.0	708	735	780	795	852	933				

Flow		Kinematic viscosity—centistokes									
US gal per min	Bbl per hr (42 gal)	26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
		Approx SSU viscosity									
		125	150	200	300	500	750	1000	1500	2000	3000
.1	.14	*1.37*	*1.66*	*2.25*	*3.38*	*5.65*	*8.45*	*11.3*	*16.9*	*22.6*	*33.8*
.3	.43	*4.12*	*4.98*	*6.75*	*10.2*	*17.0*	*25.3*	*33.8*	*50.7*	*67.8*	*102*
.5	.71	*6.86*	*8.32*	*11.3*	*16.9*	*28.3*	*42.3*	*56.4*	*85*	*113*	*169*
1	1.4	*13.7*	*16.6*	*22.5*	*33.8*	*56.5*	*84.5*	*113*	*169*	*226*	*338*
2	2.9	*27.5*	*33.2*	*45.0*	*67.6*	*113*	*169*	*226*	*338*	*452*	*676*
3	4.3	*41.2*	*49.8*	*67.5*	*102*	*170*	*253*	*338*	*507*	*678*	
4	5.7	*55.0*	*66.5*	*90.0*	*136*	*226*	*338*	*452*	*677*	*904*	
5	7.1	*68.7*	*83.2*	*113*	*169*	*283*	*423*	*564*	*846*		
6	8.6	*82.4*	*99.7*	*135*	*203*	*339*	*507*	*677*			
7	10	*96.2*	*117*	*158*	*237*	*395*	*591*	*790*			
8	11.4	*110*	*133*	*180*	*271*	*452*	*676*	*903*			
9	12.9	*124*	*156*	*203*	*303*	*508*	*760*				
10	14.3	*137*	*167*	*225*	*338*	*565*	*845*				
12	17.1	*165*	*200*	*270*	*406*	*678*					
14	20.0	*192*	*233*	*315*	*474*	*792*					
16	22.8	*220*	*266*	*360*	*541*	*904*					
18	25.7	*248*	*299*	*405*	*609*						
20	28.6	*470*	*332*	*450*	*677*						

Loss in lb per sq in = .433 (sp gr) (figures from table)

Friction Losses in Pipe; 1½ Inch (1.610″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
U S gal per min	Bbl per hr (42 gal)	.6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity									
			31.5	33	35	40	50	60	70	80	100
1	1.4	.13	*.10*	*.20*	*.25*	*.41*	*.69*	*.97*	*1.23*	*1.47*	*1.93*
2	2.9	.42	.49	*.39*	*.51*	*.83*	*1.39*	*1.93*	*2.46*	*2.94*	*3.86*
3	4.3	.86	.98	1.17	1.25	*1.24*	*2.08*	*2.89*	*3.68*	*4.41*	*5.79*
4	5.7	1.43	1.63	1.92	2.07	*1.65*	*2.78*	*3.86*	*4.91*	*5.88*	*7.72*
5	7.1	2.11	2.42	2.83	3.05	*2.06*	*3.47*	*4.82*	*6.14*	*7.35*	*9.65*
6	8.6	2.90	3.36	3.89	4.18	4.69	*4.17*	*5.79*	*7.37*	*8.82*	*11.6*
8	11.4	4.97	5.60	6.44	6.87	7.77	9.02	*7.72*	*9.83*	*11.8*	*15.5*
10	14.3	7.51	8.34	9.58	10.1	11.6	13.2	*9.65*	*12.3*	*14.7*	*19.3*
12	17.1	10.4	11.6	13.4	14.0	15.6	17.9	19.8	*14.7*	*17.6*	*23.2*
15	21.4	16.0	17.4	19.6	20.7	23.2	26.5	29.1	31.1	*21.0*	*29.0*
20	28.6	27.2	29.5	32.9	34.6	38.2	43.9	47.6	51.1	53.8	*38.6*
25	35.7	41.4	44.8	49.5	51.8	57.5	64.6	70.1	75.2	78.9	84.7
30	42.9	58.8	63.0	69.1	72.0	79.0	89.3	97.1	103	109	116.5
40	57.1	102	107	117	122	132	150	160	170	178	191
50	71.4	157	164	178	183	198	222	237	251	263	281
60	85.7	224	233	249	259	279	306	330	347	362	388
70	100	300	312	333	343	369	402	436	457	477	508
80	114	389	403	427	440	470	516	551	580	602	643
90	129	489	508	536	550	585	634	681	715	746	792
100	143	601	624	656	670	714	774	820	863	898	949

Flow		Kinematic viscosity—centistokes									
U S gal per min	Bbl per hr (42 gal)	26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	6
		Approx SSU viscosity									
		125	150	200	300	500	750	1000	1500	2000	3000
1	1.4	*2.47*	*3.00*	*4.14*	*6.09*	*10.2*	*15.2*	*20.3*	*30.4*	*40.8*	*60.9*
2	2.9	*4.95*	*6.00*	*8.28*	*12.2*	*20.3*	*30.4*	*40.6*	*60.8*	*81.5*	*122*
3	4.3	*7.42*	*9.00*	*12.4*	*18.3*	*30.4*	*45.6*	*60.9*	*91.3*	*122*	*183*
4	5.7	*9.90*	*12.0*	*16.6*	*24.4*	*40.6*	*60.8*	*81.2*	*122*	*163*	*244*
5	7.1	*12.4*	*15.0*	*20.7*	*30.4*	*50.7*	*76.0*	*102*	*152*	*204*	*304*
6	8.6	*14.9*	*18.0*	*24.8*	*36.5*	*60.8*	*91.2*	*122*	*183*	*244*	*365*
8	11.4	*19.8*	*24.0*	*33.1*	*48.7*	*81.2*	*122*	*163*	*243*	*326*	*487*
10	14.3	*24.7*	*30.0*	*41.4*	*60.9*	*102*	*152*	*203*	*304*	*408*	*609*
12	17.1	*29.7*	*36.0*	*49.7*	*73.2*	*122*	*182*	*244*	*365*	*490*	*732*
15	21.4	*37.1*	*45.0*	*62.2*	*91.4*	*152*	*228*	*304*	*457*	*612*	*914*
20	28.6	*49.5*	*60.0*	*82.8*	*122*	*203*	*304*	*406*	*608*	*815*	
25	35.7	*61.9*	*75.0*	*103*	*152*	*254*	*380*	*507*	*760*		
30	42.9	124	*90.0*	*124*	*183*	*304*	*456*	*609*	*913*		
40	57.1	204	216	*166*	*244*	*406*	*608*	*812*			
50	71.4	302	317	342	*304*	*507*	*760*				

Loss in lb per sq in = .433 (sp gr) (figures from table)

Friction Losses in Pipe; 2 inch (2.067″ inside dia)
Loss in ft of Liquid per 1000 ft of Pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
		.6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity									
US gal per min	Bbl per hr (42 gal)		31.5	33	35	40	50	60	70	80	100
1	1.4	.04	*.04*	*.07*	*.09*	*.15*	*.26*	*.36*	*.45*	*.54*	*.71*
2	2.9	.13	.15	*.15*	*.19*	*.30*	*.51*	*.71*	*.90*	*1.08*	*1.42*
4	5.7	.43	.50	.58	.63	*.59*	*1.02*	*1.42*	*1.81*	*2.17*	*2.84*
6	8.6	.87	1.00	1.20	1.27	1.46	*1.53*	*2.13*	*2.71*	*3.25*	*4.26*
8	11.4	1.47	1.68	1.97	2.13	2.38	*2.04*	*2.84*	*3.61*	*4.33*	*5.68*
10	14.3	2.20	2.55	2.90	3.09	3.52	*2.56*	*3.56*	*4.52*	*5.42*	*7.11*
12	17.1	3.06	3.46	3.97	4.23	4.78	5.57	*4.27*	*5.43*	*6.51*	*8.53*
14	20.0	4.07	4.51	5.22	5.51	6.26	7.28	*4.98*	*6.33*	*7.59*	*9.96*
16	22.8	5.17	5.79	6.65	7.01	7.92	9.16	9.95	*7.23*	*8.67*	*11.4*
18	25.7	6.44	7.16	8.18	8.63	9.67	11.2	12.6	13.1	*9.76*	*12.8*
20	28.6	7.82	8.64	9.77	10.4	11.6	13.5	14.8	15.5	*10.8*	*14.2*
25	35.7	11.9	13.0	14.7	15.4	17.2	19.9	21.6	22.8	24.1	*17.8*
30	42.9	17.0	18.2	20.4	21.5	23.8	27.2	29.9	31.2	33.0	35.6
35	50.0	22.3	24.1	27.0	28.2	31.2	35.6	38.6	40.4	43.4	47.3
40	57.1	28.8	31.0	34.2	36.0	39.6	44.6	48.8	52.9	54.1	60.7
50	71.4	44.1	47.2	52.0	54.0	59.2	66.4	72.0	76.9	78.4	86.2
60	85.7	62.7	66.5	72.2	74.2	82.3	91.8	98.6	105	111	119
70	100	84.1	88.5	95.8	99.4	108	120	130	137	145	156
80	114	109	114	123	127	138	154	166	174	182	195
90	129	137	143	154	158	171	192	204	215	225	239
100	143	167	176	188	193	208	230	244	260	269	289
110	157	202	211	225	231	246	275	290	307	319	335
120	171	238	249	265	273	290	321	341	358	375	396
130	186	277	290	307	316	335	372	392	411	432	459
140	200	320	347	352	364	383	424	449	472	491	521
150	214	366	382	403	415	437	479	510	529	553	586
160	228	414	431	457	469	494	536	572	595	621	659
170	243	467	485	513	522	553	601	639	665	694	729
180	257	524	543	572	583	619	665	714	743	767	804
190	271	584	602	634	649	688	733	792	825	846	884
200	286	643	666	699	716	756	808	851	901	927	977
210	300	709	731	768	786	826	880	935	975		
220	314	778	798	838	858	902	958				
230	328	851	873	912	934	982					
240	343	922	945	988							

Loss in lb per sq in = .433 (sp gr) (figures from table)

Friction Losses in Pipe; 2 inch (2.067″ inside dia) Loss in ft of liquid per 1000 ft of Pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
US gal per min	Bbl per hr (42 gal)	26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
		Approx SSU viscosity									
		125	150	200	300	500	750	1000	1500	2000	3000
1	1.4	*.91*	*1.10*	*1.49*	*2.24*	*3.74*	*5.60*	*7.48*	*11.2*	*15.0*	*22.4*
2	2.9	*1.82*	*2.21*	*2.98*	*4.48*	*7.49*	*11.2*	*15.0*	*22.4*	*30.0*	*44.9*
3	4.3	*2.73*	*3.31*	*4.47*	*6.73*	*11.2*	*16.8*	*22.4*	*33.6*	*45.0*	*67.4*
4	5.7	*3.64*	*4.42*	*5.96*	*8.98*	*15.0*	*22.4*	*29.9*	*44.8*	*60.0*	*89.9*
5	7.1	*4.56*	*5.52*	*7.45*	*11.2*	*18.7*	*28.0*	*37.4*	*56.0*	*75.0*	*112*
6	8.6	*5.47*	*6.63*	*8.95*	*13.5*	*22.5*	*33.6*	*44.8*	*67.2*	*90.0*	*135*
7	10.0	*6.38*	*7.73*	*10.4*	*15.7*	*26.2*	*39.2*	*52.3*	*78.4*	*105*	*157*
8	11.4	*7.29*	*8.84*	*11.9*	*18.0*	*30.0*	*34.8*	*59.8*	*89.6*	*120*	*180*
9	12.9	*8.20*	*9.94*	*13.4*	*20.2*	*33.7*	*50.4*	*67.3*	*101*	*135*	*202*
10	14.3	*9.11*	*11.0*	*14.9*	*22.4*	*37.4*	*56.0*	*74.8*	*112*	*150*	*224*
12	17.1	*10.9*	*13.3*	*18.9*	*26.9*	*44.9*	*67.3*	*89.7*	*135*	*180*	*269*
14	20.0	*12.7*	*15.5*	*20.9*	*31.4*	*52.4*	*78.4*	*105*	*157*	*210*	*314*
16	22.8	*14 6*	*17.7*	*23 9*	*35.9*	*59.9*	*89.6*	*120*	*179*	*240*	*359*
18	25.7	*16.4*	*19.9*	*26.8*	*40.3*	*67.4*	*101*	*135*	*202*	*270*	*404*
20	28.6	*18.2*	*22.1*	*29.8*	*44.9*	*74.9*	*112*	*150*	*224*	*300*	*449*
25	35.7	*22.8*	*27.6*	*37.3*	*56.1*	93.6	*140*	*187*	*280*	*375*	*562*
30	42.9	*27.3*	*33.1*	*44.7*	*67.3*	*112*	*168*	*224*	*336*	*450*	*674*
35	50.0	*31.9*	*38.7*	*52.2*	*78.5*	*131*	*196*	*262*	*392*	*525*	*786*
40	57.1	63.0	*44.2*	*59.6*	*89.8*	*150*	*224*	*299*	*448*	*600*	*899*
45	64.3	70.8	80.2	*67.1*	*101*	*168*	*252*	*336*	*503*	*675*	
50	71.4	92.8	97.1	*74.5*	*112*	*187*	*280*	*374*	*560*	*750*	
60	85.7	127	134	146	*135*	*225*	*336*	*448*	*672*	*900*	
70	100	162	176	189	*157*	*262*	*392*	*523*	*784*		
80	114	208	219	238	*180*	*300*	*448*	*598*	*896*		
90	129	257	270	293	327	*337*	*504*	*673*			
100	143	309	322	352	388	*374*	*560*	*748*			
110	157	364	379	412	465	*412*	*617*	*823*			
120	171	423	445	463	537	*449*	*673*	*898*			
130	186	487	510	549	618	*487*	*728*				
140	200	548	580	627	703	*524*	*784*				
150	214	622	655	705	792	909	*840*				
160	228	697	737	792	887		*896*				
170	243	775	808	882			*952*				
180	257	858	871	962							
190	271	947	986								

Loss in lb per sq in = .433 (sp gr) (figures from table)

Friction Losses in Pipe; 2½ inch (2.469″ inside dia)
Loss in ft of Liquid per 1000 ft of Pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
U S gal per min	Bbl per hr (42 gal)	.6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity									
			31.5	33	35	40	50	60	70	80	100
10	14.3	.92	1.05	1.23	1.31	1.48	*1.26*	*1.75*	*2.22*	*2.66*	*3.50*
12	17.1	1.28	1.47	1.70	1.80	2.04	*1.51*	*2.10*	*2.67*	*3.19*	*4.19*
14	20.0	1.68	1.92	2.23	2.37	2.65	3.09	*2.45*	*3.11*	*3.73*	*4.89*
16	22.8	2.15	2.43	2.81	2.99	3.34	3.86	*2.80*	*3.56*	*4.26*	*5.59*
18	25.7	2.68	2.99	3.46	3.68	4.21	4.77	5.26	*4.00*	*4.80*	*6.28*
20	28.6	3.23	3.61	4.27	4.42	4.94	5.73	6.26	*4.44*	*5.33*	*6.98*
25	35.7	4.88	5.39	6.17	6.55	7.31	8.42	9.20	9.79	*6.66*	*8.73*
30	42.9	6.87	7.57	8.55	9.07	10.1	11.5	12.6	13.5	14.1	*10.5*
35	50.0	9.18	9.97	11.3	11.8	13.3	15.1	16.4	17.7	18.5	20.0
40	57.1	11.8	12.8	14.3	15.0	16.8	19.0	20.7	22.1	23.2	25.0
45	64.3	14.8	15.9	17.7	18.7	20.8	23.5	25.6	27.1	28.4	30.6
50	71.4	18.1	19.3	21.4	22.4	24.9	28.3	30.6	32.5	34.1	36.8
60	85.7	25.6	27.2	29.9	31.1	34.2	39.1	42.1	44.7	46.7	50.4
70	100	34.2	36.2	39.6	41.4	45.2	51.4	55.4	58.5	61.5	66.0
80	114	44.1	46.7	50.6	53.0	57.3	64.5	69.7	74.2	77.5	82.7
90	129	55.2	58.8	63.2	65.4	70.9	80.0	86.6	91.2	95.3	103
100	143	67.2	72.3	76.7	79.4	85.8	96.3	104	109	115	123
110	157	80.9	86.2	92.4	94.8	103	113	121	130	135	146
120	171	95.7	102	108	112	121	133	143	151	158	169
130	186	112	118	125	130	139	155	166	176	181	194
140	200	129	136	144	150	160	176	188	198	209	221
150	214	147	155	165	170	181	198	212	223	234	250
160	228	167	175	187	191	203	224	238	253	262	281
170	243	188	196	210	214	226	248	267	283	290	312
180	257	210	219	234	239	253	277	297	311	322	345
190	271	233	243	260	265	280	306	328	339	356	378
200	286	258	269	286	292	308	334	357	373	391	417
220	314	310	322	343	351	369	400	427	448	461	486
240	343	367	381	404	416	436	469	494	522	539	573
260	371	429	445	470	482	505	543	575	599	621	660
280	400	497	513	540	556	580	630	657	686	710	758
300	429	568	586	617	632	659	705	748	775	803	849
320	457	643	663	695	716	747	799	837	875	903	952
340	486	725	745	776	800	839	894	933	980		
360	514	809	835	866	892	936	994				

Loss in lb per sq in = .433 (sp gr) (figures from table)

Friction Losses in Pipe; 2½ inch (2.469″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow: US gal per min	Flow: Bbl per hr (42 gal)	Kinematic viscosity—centistokes 26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
		Approx SSU viscosity 125	150	200	300	500	750	1000	1500	2000	3000
1	1.4	*.45*	*.54*	*.73*	*1.10*	*1.84*	*2.75*	*3.67*	*5.52*	*7.38*	*11.0*
2	2.9	*.90*	*1.09*	*1.47*	*2.20*	*3.68*	*5.50*	*7.35*	*11.0*	*14.8*	*22.0*
4	5.7	*1.79*	*2.17*	*2.93*	*4.41*	*7.36*	*11.0*	*14.7*	*22.1*	*29.5*	*44.1*
6	8.6	*2.69*	*3.26*	*4.40*	*6.62*	*11.0*	*16.5*	*22.0*	*33.1*	*44.3*	*66.2*
8	11.4	*3.58*	*4.34*	*5.87*	*8.82*	*14.7*	*22.0*	*29.4*	*44.1*	*59.1*	*88.2*
10	14.3	*4.48*	*5.43*	*7.33*	*11.0*	*18.4*	*27.5*	*36.7*	*55.2*	*73.8*	*110*
12	17.1	*5.38*	*6.51*	*8.80*	*13.2*	*22.1*	*33.0*	*44.1*	*66.2*	*88.6*	*132*
14	20.0	*6.27*	*7.60*	*10.3*	*15.4*	*25.7*	*38.5*	*51.4*	*77.2*	*103*	*154*
16	22.8	*7.16*	*8.68*	*11 7*	*17.6*	*29.4*	*44.0*	*58.8*	*88.2*	*118*	*176*
18	25.7	*8.06*	*9.77*	*13.2*	*19.8*	*33.1*	*49.5*	*66.1*	*99.3*	*133*	*198*
20	28.6	*8.96*	*10.9*	*14.7*	*22.0*	*36.8*	*55.0*	*73.4*	*110*	*148*	*220*
25	35.7	*11.2*	*13.6*	*18.3*	*27.6*	*46.0*	*68.8*	*91.8*	*138*	*185*	*276*
30	42.9	*13.4*	*16.3*	*22.0*	*33.1*	*55.2*	*82.5*	*110*	*165*	*222*	*331*
35	50.0	*15.7*	*19.0*	*25.6*	*38 6*	*64.4*	*96.3*	*129*	*193*	*258*	*386*
40	57.1	*17.9*	*21.7*	*29.3*	*44.2*	*73.6*	*110*	*147*	*221*	*295*	*441*
45	64.3	33.0	*24.4*	*33 0*	*49.6*	*82.8*	*124*	*165*	*248*	*332*	*496*
50	71.4	39.2	*27.2*	*36.6*	*55.2*	*92.0*	*138*	*184*	*276*	*369*	*551*
60	85.7	54.0	56.5	*44.0*	*66.2*	*110*	*165*	*220*	*331*	*443*	*662*
70	100	70 0	73.5	*51.3*	*77.2*	*129*	*193*	*257*	*386*	*517*	*772*
80	114	87.7	93.4	101	*88.3*	*147*	*220*	*294*	*441*	*591*	*882*
90	129	110	115	125	*99.3*	*166*	*248*	*330*	*497*	*665*	*993*
100	143	130	137	148	*110*	*184*	*275*	*367*	*552*	*738*	
110	157	154	164	176	197	*202*	*303*	*403*	*607*	*812*	
120	171	180	188	205	226	*221*	*330*	*441*	*662*	*886*	
130	186	206	216	232	263	*239*	*358*	*477*	*717*	*960*	
140	200	234	247	267	299	*257*	*385*	*514*	*772*		
150	214	265	279	305	333	*276*	*413*	*551*	*827*		
160	228	296	312	338	374	*294*	*440*	*588*	*882*		
170	243	328	345	373	415	*312*	*468*	*624*	*937*		
180	257	364	384	412	461	530	*495*	*661*	*993*		
190	271	403	420	454	514	587	*523*	*698*			
200	286	438	457	493	550	628	*550*	*734*			
220	314	522	540	586	658	752	*605*	*808*			
240	343	612	633	682	760	866	*660*	*881*			
260	371	711	732	782	867		*715*	*955*			

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 3 inch (3.068″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow: US gal per min	Flow: Bbl per hr (42 gal)	Kinematic viscosity—centistokes: .6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity	31.5	33	35	40	50	60	70	80	100
8	11.4	.22	.25	.29	.32	*.24*	*.42*	*.59*	*.74*	*.89*	*1.18*
10	14.3	.32	.37	.43	.47	.54	*.53*	*.73*	*.93*	*1.11*	*1.47*
15	21.4	.70	.76	.89	.94	1.07	*.79*	*1.10*	*1.40*	*1.67*	*2.20*
20	28.6	1.12	1.27	1.47	1.57	1.78	2.07	*1.46*	*1.86*	*2.23*	*2.93*
25	35.7	1.69	1.93	2.23	2.31	2.61	3.01	3.29	*2.33*	*2.79*	*3.66*
30	42.9	2.36	2.64	2.99	3.22	3.60	4.12	4.50	4.83	*3.35*	*4.40*
35	50.0	3.13	3.48	3.97	4.21	4.66	5.41	5.89	6.35	6.61	*5.13*
40	57.1	4.03	4.42	5.02	5.29	5.90	6.80	7.46	7.93	8.37	*5.87*
50	71.4	6.10	6.70	7.50	7.93	8.76	10.1	10.9	11.7	12.3	13.2
60	85.7	8.57	9.32	10.4	11.0	12.0	13.7	15.0	16.0	16.8	18.0
70	100	11.5	12.4	13.8	14.5	15.9	18.0	19.6	20.9	21.9	23.6
80	114	14.7	15.9	17.5	18.4	20.3	22.9	24.6	26.4	27.7	29.8
90	129	18.4	19.9	21.8	22.8	25.0	28.0	30.4	32.4	33.8	36.3
100	143	22.4	24.2	26.3	27.5	30.2	33.7	36.4	39.0	40.8	43.6
120	171	31.8	34.1	36.9	38.6	41.9	46.8	50.5	53.4	56.4	60.0
140	200	42.4	45.6	49.4	50.9	55.4	65.5	66.0	70.0	73.2	78.6
160	228	54.8	58.0	63.3	65.4	70.4	79.1	83.8	87.9	92.3	98.2
180	257	69.0	72.7	78.7	81.6	87.2	97.2	104	109	114	122
200	286	84.7	88.9	95.7	99.4	106	117	125	131	137	146
225	322	107	112	120	124	132	145	155	164	169	180
250	357	131	137	147	151	160	175	188	195	204	218
275	393	158	164	175	180	191	208	226	233	243	258
300	429	187	193	204	212	225	244	260	273	281	298
325	464	218	225	238	247	261	283	300	316	325	345
350	500	253	260	275	283	300	324	344	361	373	396
375	536	288	298	314	322	341	367	388	407	424	448
400	571	328	339	354	363	385	414	436	458	476	498
425	607	368	381	397	407	432	463	488	511	529	550
450	643	410	427	443	455	480	515	543	568	587	619
475	679	457	473	493	504	532	571	599	625	646	682
500	714	504	524	544	555	587	627	658	684	707	750
525	750	555	574	597	609	644	688	720	748	770	821
550	786	606	627	651	665	703	748	783	814	838	890
575	822	663	685	708	723	761	814	852	886	912	962
600	857	721	742	767	783	820	882	919	960	989	

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 3 inch (3.068″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow: US gal per min	Flow: Bbl per hr (42 gal)	Kinematic viscosity—centistokes: 26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
		Approx SSU viscosity: 125	**150**	**200**	**300**	**500**	**750**	**1000**	**1500**	**2000**	**3000**
4	5.7	*.75*	*.91*	*1.23*	*1.85*	*3.08*	*4.62*	*6.16*	*9.25*	*12.4*	*18.5*
6	8.6	*1.13*	*1.37*	*1.84*	*2.77*	*4.62*	*6.92*	*9.24*	*13.9*	*18.5*	*27.7*
8	11.4	*1.50*	*1.82*	*2.45*	*3.70*	*6.16*	*9.23*	*12.3*	*18.5*	*24.7*	*36.9*
10	14.3	*1.88*	*2.28*	*3.06*	*4.62*	*7.70*	*11.5*	*15.4*	*23.1*	*30.9*	*46.2*
12	17.1	*2.25*	*2.73*	*3.68*	*5.55*	*9.24*	*13.8*	*18.5*	*27.7*	*37.1*	*55.5*
14	20.0	*2.63*	*3.18*	*4.29*	*6.47*	*10.8*	*16.2*	*21.5*	*32.3*	*43.3*	*64.7*
16	22.8	*3.00*	*3.64*	*4.90*	*7.39*	*12.3*	*18.5*	*24.6*	*37.0*	*49.5*	*73.9*
18	25.7	*3.38*	*4.09*	*5.52*	*8.31*	*13.9*	*20.8*	*27.7*	*41.6*	*55.6*	*83.2*
20	28.6	*3.76*	*4.55*	*6.13*	*9.24*	*15.4*	*23.1*	*30.8*	*46.2*	*61.8*	*92.4*
25	35.7	*4.69*	*5.69*	*7.67*	*11.5*	*19.3*	*28.8*	*38.5*	*57.7*	*77.3*	*115*
30	42.9	*5.63*	*6.83*	*9.20*	*13.9*	*23.1*	*34.6*	*46.2*	*69.3*	*92.7*	*139*
35	50.0	*6.57*	*7.97*	*10.7*	*16.2*	*27.0*	*40.3*	*53.8*	*80.9*	*108*	*162*
40	57.1	*7.51*	*9.10*	*12.3*	*18.5*	*30.8*	*46.2*	*61.6*	*92.5*	*124*	*185*
50	71.4	*9.39*	*11.4*	*15.3*	*23.1*	*38.5*	*57.7*	*77.0*	*115*	*154*	*231*
60	85.7	19.2	*13.7*	*18.4*	*27.7*	*46.2*	*69.2*	*92.4*	*139*	*185*	*277*
70	100	25.3	26.8	*21.5*	*32.3*	*53.9*	*80.8*	*108*	*162*	*216*	*323*
80	114	31.6	33.6	*24.7*	*37.0*	*61.6*	*92.3*	*123*	*185*	*247*	*369*
90	129	38.9	40.9	44.6	*41.6*	*69.3*	*104*	*139*	*208*	*278*	*416*
100	143	46.1	49.5	53.0	*46.2*	*77.0*	*115*	*154*	*231*	*309*	*462*
120	171	64.0	67.6	72.9	*55.5*	*92.4*	*138*	*185*	*277*	*371*	*555*
140	200	83.9	89.1	94.9	108	*108*	*162*	*215*	*323*	*433*	*647*
160	228	106	111	120	135	*123*	*185*	*246*	*370*	*495*	*739*
180	257	131	137	148	164	*139*	*208*	*277*	*416*	*556*	*832*
200	286	157	163	179	198	*154*	*231*	*308*	*462*	*618*	*924*
225	322	191	204	223	242	279	*260*	*346*	*520*	*696*	
250	357	229	242	261	291	332	*288*	*385*	*577*	*773*	
275	393	271	285	311	343	396	*317*	*423*	*635*	*850*	
300	429	316	331	361	398	456	*346*	*462*	*693*	*927*	
325	464	364	381	416	458	527	*375*	*500*	*751*		
350	500	415	436	467	523	593	672	*538*	*809*		
375	536	469	493	528	586	672	746	*577*	*867*		
400	571	526	550	592	656	751	843	*616*	*925*		
425	607	587	612	656	728	834	937	*654*	*982*		
450	643	652	675	728	802	928					
475	679	718	744	801	889						

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 3½ inch (3.548″ inside dia) Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow: US gal per min	Flow: Bbl per hr (42 gal)	Kinematic viscosity—centistokes: .6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
	Approx SSU viscosity		31.5	33	35	40	50	60	70	80	100
20	28.6	.56	.63	.72	.78	.88	1.03	*.82*	*1.04*	*1.25*	*1.64*
25	35.7	.82	.93	1.08	1.14	1.29	1.52	1.67	*1.30*	*1.56*	*2.05*
30	42.9	1.15	1.29	1.50	1.57	1.78	2.09	2.30	*1.56*	*1.87*	*2.46*
35	50.0	1.53	1.70	1.94	2.08	2.31	2.68	2.97	3.18	*2.18*	*2.87*
40	57.1	1.95	2.17	2.49	2.68	2.91	3.35	3.70	4.00	4.21	*3.28*
45	64.3	2.46	2.68	3.03	3.22	3.59	4.11	4.57	4.91	5.19	*3.69*
50	71.4	2.95	3.25	3.68	3.90	4.32	4.98	5.42	5.87	6.20	6.64
60	85.7	4.17	4.54	5.12	5.38	6.00	6.82	7.41	7.97	8.41	9.21
70	100	6.78	6.02	6.78	7.11	7.84	8.87	9.76	10.4	10.9	11.9
80	114	7.19	7.72	8.57	8.79	9.81	11.2	12.3	13.0	13.7	14.9
90	129	8.92	9.59	10.6	11.2	12.5	13.9	15.0	16.1	16.8	18.3
100	143	10.8	11.7	12.9	13.6	14.8	16.8	18.0	19.3	20.2	21.7
120	171	15.4	16.4	18.1	18.7	20.5	22.9	25.0	26.3	27.7	29.7
140	200	20.5	22.0	23.9	24.9	27.3	30.5	33.1	34.6	36.0	39.1
160	228	26.4	28.3	30.9	31.9	35.0	38.4	41.8	43.9	45.6	49.0
180	257	33.0	35.0	38.0	39.6	42.5	47.7	50.8	54.0	56.3	60.1
200	286	40.3	43.0	46.3	48.0	51.4	57.1	61.8	65.5	68.0	72.2
225	322	50.7	53.2	57.7	59.7	64.7	71.2	75.9	80.1	84.3	88.8
250	357	62.6	65.0	70.9	72.7	78.9	86.5	92.7	96.9	101	107
275	393	75.4	77.9	84.6	87.1	93.3	102	110	115	120	127
300	429	89.2	92.2	99.6	103	109	119	128	135	140	148
325	464	104	108	116	120	127	138	147	154	161	171
350	500	121	124	133	138	146	159	169	178	183	194
375	536	138	142	152	157	167	181	191	200	207	220
400	571	156	161	171	178	188	203	213	225	233	248
425	607	176	181	192	200	211	225	238	252	259	279
450	643	196	203	213	221	234	250	265	280	287	309
475	679	219	225	235	244	257	276	292	310	319	336
500	714	241	249	259	268	282	304	321	340	350	368
550	786	290	300	311	323	340	365	385	407	415	440
600	857	343	355	367	377	399	426	452	466	480	510
650	929	400	414	428	440	461	498	522	540	557	587
700	1000	464	480	494	505	532	572	597	621	637	675
750	1070	532	548	567	576	604	651	682	704	725	769
800	1140	606	624	641	652	684	730	765	794	815	861

Loss in lb per sq in = .433 (sp gr) (figures in table)

The National Bureau of standards has recommended the elimination of this pipe size.

Friction Losses in Pipe; 3½ inch (3.548″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
		26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
		Approx SSU viscosity									
US gal per min	Bbl per hr (42 gal)	125	150	200	300	500	750	1000	1500	2000	3000
10	14.3	*1.05*	*1.27*	*1.72*	*2.58*	*4.32*	*6.46*	*8.62*	*12.9*	*16.9*	*25.8*
15	21.4	*1.57*	*1.91*	*2.58*	*3.88*	*6.47*	*9.68*	*12.9*	*19.4*	*25.4*	*38.8*
20	28.6	*2.10*	*2.54*	*3.44*	*5.17*	*8.63*	*12.9*	*17.3*	*25.8*	*33.8*	*51.7*
25	35.7	*2.62*	*3.18*	*4.29*	*6.47*	*10.8*	*16.1*	*21.6*	*32.3*	*42.3*	*64.7*
30	42.9	*3.15*	*3.82*	*5.15*	*7.76*	*13.0*	*19.4*	*25.9*	*38.8*	*50.7*	*77.6*
35	50.0	*3.67*	*4.45*	*6.01*	*9.05*	*15.1*	*22.6*	*30.2*	*45.3*	*59.2*	*90.6*
40	57.1	*4.20*	*5.09*	*6.87*	*10.3*	*17.3*	*25.8*	*34.5*	*51.7*	*67.6*	*103*
45	64.3	*4.72*	*5.73*	*7.73*	*11.6*	*19.4*	*29.0*	*38.8*	*58.2*	*76.1*	*116*
50	71.4	*5.25*	*6.36*	*8.59*	*12.9*	*21.6*	*32.3*	*43.1*	*64.7*	*84.5*	*129*
60	85.7	*6.30*	*7.64*	*10.3*	*15.5*	*25.9*	*38.8*	*51.8*	*77.6*	*101*	*155*
70	100	12.8	*8.91*	*12.0*	*18.1*	*30.2*	*45.2*	*60.4*	*90.6*	*118*	*181*
80	114	16.1	16.9	*13.7*	*20.7*	*34.5*	*51.6*	*69.0*	*103*	*135*	*207*
90	129	19.6	20.8	*15.5*	*23.3*	*38.8*	*58.1*	*77.6*	*116*	*152*	*233*
100	143	23.6	24.8	*17.2*	*25.9*	*43.2*	*64.6*	*86.2*	*129*	*169*	*258*
120	171	31.9	34.0	37.1	*31.0*	*51.8*	*77.5*	*104*	*155*	*203*	*310*
140	200	41.5	43.8	48.2	*36.2*	*60.4*	*90.4*	*121*	*181*	*236*	*362*
160	228	52.3	55.3	60.5	67.7	*69.1*	*103*	*138*	*207*	*270*	*413*
180	257	64.6	67.3	73.9	83.4	*77.7*	*116*	*155*	*233*	*304*	*466*
200	286	77.3	81.5	87.9	99.9	*86.3*	*129*	*173*	*258*	*338*	*517*
225	322	94.4	99.8	108	122	*97.1*	*145*	*194*	*291*	*380*	*582*
250	357	114	120	129	146	*108*	*161*	*216*	*323*	*422*	*647*
275	393	134	141	153	172	199	*177*	*237*	*356*	*465*	*711*
300	429	157	164	178	198	233	*194*	*259*	*388*	*507*	*776*
325	464	181	188	205	227	266	*210*	*280*	*420*	*549*	*840*
350	500	206	215	233	258	301	*226*	*302*	*452*	*592*	*906*
375	536	234	245	262	291	339	*242*	*323*	*485*	*634*	*970*
400	571	261	274	291	326	379	423	*345*	*517*	*676*	
425	607	291	303	325	363	419	473	*367*	*550*	*718*	
450	643	322	337	359	402	462	525	*388*	*582*	*761*	
475	679	353	368	395	440	505	572	*410*	*614*	*803*	
500	714	389	403	433	482	551	626	*431*	*647*	*845*	
550	786	459	481	514	566	648	733	795	*712*	*930*	
600	857	538	566	600	658	749	851	923	*776*		
650	929	620	648	690	755	865	978		*841*		
700	1000	708	735	789	863	987			*906*		

Loss in lb per sq in = .433 (sp gr) (figures in table)

The National Bureau of standards has recommended the elimination of this pipe size.

Friction Losses in Pipe; 4 inch (4.026″ inside dia) Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
US gal per min	Bbl per hr (42 gal)	.6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity									
			31.5	33	35	40	50	60	70	80	100
20	28.6	.30	.34	.40	.43	.49	.57	*.50*	*.63*	*.75*	*.99*
30	42.9	.62	.70	.82	.87	.98	1.14	1.25	*.95*	*1.13*	*1.48*
40	57.1	1.05	1.18	1.35	1.44	1.62	1.86	2.04	2.20	*1.51*	*1.96*
50	71.4	1.58	1.76	2.02	2.13	2.37	2.75	3.00	3.21	3.40	*2.47*
60	85.7	2.22	2.44	2.80	2.93	3.27	3.77	4.12	3.29	4.62	5.01
70	100	2.96	3.24	3.69	3.88	4.31	4.93	5.39	5.72	6.03	6.53
80	114	3.79	4.16	4.67	4.93	5.44	6.20	6.78	7.23	7.55	8.17
90	129	4.72	5.15	5.77	6.08	6.72	7.63	8.32	8.87	9.29	10.0
100	143	5.77	6.27	6.91	7.33	8.12	9.15	9.97	10.6	11.2	12.0
120	171	8.09	8.81	9.66	10.2	11.2	12.7	13.6	14.6	15.3	16.5
140	200	10.8	11.7	12.9	13.4	14.8	16.6	17.9	19.0	20.0	21.6
160	228	13.9	15.0	16.4	17.1	18.8	21.1	22.7	24.0	25.2	27.2
180	257	17.4	18.7	20.4	21.5	23.2	26.0	28.1	29.6	30.8	33.3
200	286	21.4	22.7	24.9	25.9	28.0	31.4	33.7	35.7	36.9	40.0
220	314	25.6	27.2	29.8	30.8	33.2	37.3	40.2	42.3	44.0	47.0
240	343	30.3	32.0	34.9	36.1	38.8	43.4	46.8	49.1	51.4	54.6
260	371	35.4	37.2	40.4	42.0	45.0	50.1	53.9	56.7	59.3	62.7
280	400	40.8	42.7	46.4	48.2	51.7	57.4	61.6	65.0	67.4	71.3
300	429	46.6	48.7	53.0	54.8	58.8	64.9	69.6	73.3	76.0	81.0
350	500	62.7	65.6	70.6	72.8	77.9	85.4	91.2	96.2	101	107
400	571	81.4	84.7	90.4	93.7	99.8	109	116	122	127	135
450	643	102	106	113	117	124	135	144	151	157	167
500	714	125	130	137	142	151	164	174	182	189	201
550	786	151	157	165	170	180	195	206	216	224	239
600	857	179	185	195	200	212	229	242	253	263	278
650	929	209	216	228	231	246	266	280	291	303	319
700	1000	242	249	260	267	283	306	322	333	346	365
750	1070	276	285	298	305	321	348	366	377	391	414
800	1140	314	324	337	345	362	392	411	426	439	465
850	1215	355	364	378	387	406	438	459	476	489	519
900	1285	396	408	424	434	453	486	510	531	543	574
950	1360	441	451	470	481	502	536	563	584	600	632
1000	1430	488	500	521	527	550	591	621	641	662	694
1100	1570	587	602	627	634	659	708	740	765	790	822
1200	1715	699	712	741	754	780	835	869	898	924	966

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 4 inch (4.026″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
		26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
US gal per min	Bbl per hr (42 gal)	Approx SSU viscosity									
		125	150	200	300	500	750	1000	1500	2000	3000
15	21.4	*.95*	*1.15*	*1.55*	*2.34*	*3.91*	*5.85*	*7.80*	*11.7*	*15.7*	*23.4*
20	28.6	*1.27*	*1.54*	*2.07*	*3.12*	*5.21*	*7.80*	*10.4*	*15.6*	*20.9*	*31.2*
30	42.9	*1.90*	*2.30*	*3.11*	*4.68*	*7.82*	*11.7*	*15.6*	*23.4*	*31.3*	*46.8*
40	57.1	*2.54*	*3.08*	*4.15*	*6.25*	*10.4*	*15.6*	*20.8*	*31.2*	*41.8*	*62.5*
50	71.4	*3.17*	*3.84*	*5.18*	*7.81*	*13.0*	*19.5*	*26.0*	*39.0*	*52.2*	*78.1*
60	85.7	*3.80*	*4.61*	*6.22*	*9.37*	*15.6*	*23.4*	*31.2*	*46.8*	*62.7*	*93.7*
70	100	*4.44*	*5.38*	*7.25*	*10.9*	*18.2*	*27.3*	*36.4*	*54.6*	*73.2*	*109*
80	114	8.81	*6.15*	*8.29*	*12.5*	*20.8*	*31.2*	*41.6*	*62.4*	*83.6*	*125*
90	129	10.8	11.3	*9.33*	*14.1*	*23.4*	*35.1*	*46.8*	*70.2*	*94.1*	*141*
100	143	12.9	13.7	*10.4*	*15.6*	*26.0*	*39.0*	*52.0*	*78.0*	*105*	*156*
120	171	17.6	18.6	20.3	*18.8*	*31.2*	*46.8*	*62.4*	*93.7*	*125*	*187*
140	200	22.9	24.3	26.5	*21.9*	*36.4*	*54.6*	*72.8*	*109*	*146*	*218*
160	228	29.0	30.3	33.2	*25.0*	*41.7*	*62.4*	*83.2*	*125*	*167*	*250*
180	257	35.5	37.4	40.7	45.7	*46.9*	*70.2*	*93.6*	*140*	*188*	*281*
200	286	42.6	45.0	48.7	54.8	*52.1*	*78.0*	*104*	*156*	*209*	*312*
220	314	50.3	53.0	57.1	64.7	*57.3*	*85.8*	*114*	*172*	*230*	*343*
240	343	58.5	61.5	65.1	74.7	*62.5*	*93.6*	*125*	*187*	*251*	*375*
260	371	67.2	70.8	76.8	85.7	*67.7*	*101*	*135*	*203*	*272*	*406*
280	400	76.4	80.5	87.2	97.3	*73.0*	*109*	*146*	*218*	*292*	*437*
300	429	85.8	90.8	98.5	110	127	*117*	*156*	*234*	*313*	*468*
325	464	98.5	104	113	125	146	*127*	*169*	*254*	*340*	*508*
350	500	112	118	128	143	166	*136*	*182*	*273*	*366*	*547*
375	536	127	133	145	161	187	*146*	*195*	*293*	*392*	*585*
400	571	143	149	162	180	208	*156*	*208*	*312*	*418*	*625*
450	643	178	184	198	222	254	285	*234*	*351*	*470*	*703*
500	714	213	221	237	265	305	343	*260*	*390*	*523*	*781*
550	786	252	263	280	313	360	404	*286*	*429*	*575*	*860*
600	857	296	305	328	364	417	467	507	*468*	*627*	*937*
650	929	338	353	378	419	480	528	583	*507*	*680*	
700	1000	386	402	433	474	546	608	663	*546*	*732*	
750	1070	437	455	488	533	616	685	745	*585*	*784*	
800	1140	490	510	546	570	687	764	830	*624*	*836*	
850	1215	544	570	608	663	763	848	920	*663*	*889*	
900	1285	603	629	674	739	844	939			*941*	
950	1360	666	696	743	813	927				*993*	

Loss in lb per sq in = .433 (sp gr) (figures from table)

Friction Losses in Pipe; 6 inch (6.065″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
US gal per min	Bbl per hr (42 gal)	.6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity									
			31.5	33	35	40	50	60	70	80	100
75	107	.45	.49	.58	.61	.68	.80	.86	.93	.98	*.72*
100	143	.77	.85	.96	1.01	1.14	1.30	1.42	1.52	1.62	1.74
125	178	1.14	1.27	1.43	1.51	1.68	1.95	2.10	2.23	2.35	2.57
150	214	1.61	1.78	2.01	2.09	2.32	2.66	2.86	3.08	3.20	3.46
175	250	2.13	2.37	2.63	2.79	3.04	3.52	3.74	3.97	4.24	4.51
200	286	2.75	3.00	3.34	3.55	3.85	4.41	4.76	5.02	5.31	5.69
225	322	3.42	3.74	4.17	4.38	4.78	5.39	5.89	6.16	6.45	7.05
250	357	4.15	4.55	5.07	5.21	5.76	6.94	7.11	7.47	7.77	8.41
275	393	4.99	5.42	6.02	6.28	6.88	7.60	8.35	8.86	9.18	9.81
300	429	5.87	6.38	7.06	7.37	8.09	8.94	9.69	10.3	10.8	11.4
350	500	7.90	8.45	9.38	9.80	10.5	11.8	12.6	13.5	14.2	15.0
400	571	10.2	10.9	11.8	12.5	13.4	15.0	16.0	17.0	18.0	19.1
450	643	12.8	13.6	14.8	15.5	16.7	18.5	19.7	20.1	21.8	23.7
500	714	15.6	16.6	18.0	18.7	20.4	22.6	24.0	25.1	26.4	28.5
550	786	18.8	19.8	21.5	22.3	24.3	26.8	28.5	29.6	29.9	33.4
600	857	22.1	23.3	25.1	26.2	28.4	31.1	33.2	35.0	36.2	38.8
650	929	25.8	27.2	29.2	30.4	32.8	36.1	38.5	40.4	41.8	44.7
700	1000	29.7	31.2	33.5	34.9	37.5	41.1	44.2	46.3	47.9	51.3
750	1070	33.9	35.6	38.2	39.7	42.5	46.7	49.9	51.8	54.0	57.2
800	1140	38.3	40.5	43.2	44.4	47.8	52.7	56.1	58.5	60.9	64.3
900	1285	48.5	50.7	54.4	55.6	59.3	65.4	69.1	72.8	74.6	79.9
1000	1430	59.5	62.2	66.4	67.5	72.4	79.3	83.4	87.6	91.0	95.9
1100	1570	71.6	74.8	79.4	80.8	86.7	94.5	99.6	104	109	114
1200	1715	84.6	87.9	93.4	95.6	102	111	117	121	126	133
1400	2000	115	118	126	128	135	146	155	161	167	177
1600	2285	150	153	162	164	173	187	199	207	213	224
1800	2570	188	193	203	206	216	232	246	256	264	278
2000	2860	231	237	247	253	264	284	296	311	320	334
2200	3140	277	286	297	303	316	338	354	371	382	398
2400	3430	330	341	352	356	374	395	417	430	448	470
2600	3710	387	395	408	418	433	461	485	500	520	543
2800	4000	449	458	470	482	497	526	553	574	595	621
3000	4285	515	526	536	550	567	597	628	655	666	706
3250	4640	605	613	629	641	665	701	729	757	777	817
3500	5000	697	711	729	739	771	808	841	869	897	938

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 6 inch (6.065″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
		26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
U S gal per min	Bbl per hr (42 gal)	Approx SSU viscosity									
		125	150	200	300	500	750	1000	1500	2000	3000
50	71.4	*.62*	*.74*	*1.00*	*1.51*	*2.52*	*3.78*	*5.04*	*7.57*	*10.1*	*15.1*
75	107	*.92*	*1.12*	*1.51*	*2.27*	*3.78*	*5.66*	*7.56*	*11.4*	*15.2*	*22.7*
100	143	*1.23*	*1.49*	*2.01*	*3.03*	*5.05*	*7.55*	*10.1*	*15.1*	*20.3*	*30.2*
125	178	2.75	*1.86*	*2.51*	*3.79*	*6.31*	*9.45*	*12.6*	*18.9*	*25.3*	*37.8*
150	214	3.75	3.96	*3.01*	*4.54*	*7.58*	*11.3*	*15.1*	*22.7*	*30.4*	*45.4*
175	250	4.90	5.17	5.62	*5.30*	*8.84*	*13.2*	*17.6*	*26.5*	*35.5*	*53.0*
200	286	6.10	6.51	7.07	*6.06*	*10.1*	*15.1*	*20.2*	*30.3*	*40.5*	*60.6*
225	322	7.43	7.93	8.66	*6.82*	*11.4*	*17.0*	*22.7*	*34.1*	*45.6*	*68.1*
250	357	8.91	9.43	10.4	*7.57*	*12.6*	*18.9*	*25.2*	*37.8*	*50.7*	*75.7*
275	393	10.6	11.1	12.2	13.7	*13.9*	*20.8*	*27.7*	*41.7*	*55.8*	*83.2*
300	429	12.3	12.9	14.2	15.9	*15.1*	*22.6*	*30.2*	*45.4*	*60.9*	*90.8*
350	500	15.9	17.1	18.3	20.8	*17.7*	*26.4*	*35.3*	*53.0*	*71.0*	*106*
400	571	20.1	21.3	23.1	26.2	*20.2*	*30.2*	*40.3*	*60.6*	*81.1*	*121*
450	643	24.7	26.0	28.6	31.9	36.9	*34.0*	*45.3*	*68.2*	*91.3*	*136*
500	714	30.0	31.3	34.1	38.0	44.2	*37.8*	*50.4*	*75.7*	*101*	*151*
550	786	35.6	36.9	40.2	44.6	52.1	*41.6*	*55.4*	*83.3*	*112*	*166*
600	857	41.5	43.1	46.4	51.7	59.1	*45.3*	*60.5*	*90.9*	*122*	*182*
650	929	47.7	50.0	53.4	59.6	69.4	*49.1*	*65.5*	*98.5*	*132*	*197*
700	1000	54.1	57.0	60.8	68.6	78.8	88.3	*70.6*	*106*	*142*	*212*
750	1070	60.8	64.4	68.5	76.8	88.5	99.4	*75.6*	*114*	*152*	*227*
800	1140	68.0	72.1	76.9	85.7	97.8	111	*80.6*	*121*	*162*	*242*
900	1285	83.9	88.5	95.2	105	120	136	148	*136*	*183*	*272*
1000	1430	101	106	115	126	144	163	177	*151*	*203*	*302*
1100	1570	120	125	136	148	171	192	208	*167*	*223*	*333*
1200	1715	140	146	158	173	200	220	242	*182*	*243*	*363*
1400	2000	184	193	206	230	258	287	316	353	*284*	*424*
1600	2285	234	244	260	288	323	363	393	445	*324*	*484*
1800	2570	292	299	322	350	399	452	480	543	*591*	*545*
2000	2860	350	364	387	425	481	535	576	652	*707*	*605*
2200	3140	417	435	459	510	573	628	683	771	*833*	*666*
2400	3430	487	507	535	585	668	730	799	885	968	*726*
2600	3710	564	587	620	677	769	841	913			*787*
2800	4000	645	669	714	773	874	954				
3000	4285	734	751	805	867	993					
3200	4570	827	850	909	982						

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 8 inch (7.981″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

For clean steel pipe

Flow		Kinematic viscosity—centistokes									
U S gal per min	Bbl per hr (42 gal)	.6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity									
			31.5	33	35	40	50	60	70	80	100
150	214	.42	.47	.53	.56	.63	.72	.79	.84	.88	.96
200	286	.71	.78	.89	.94	1.05	1.15	1.30	1.38	1.45	1.57
250	357	1.07	1.18	1.33	1.40	1.56	1.77	1.92	2.04	2.14	2.30
300	429	1.50	1.65	1.85	1.94	2.15	2.43	2.65	2.80	2.93	3.15
350	500	2.01	2.19	2.45	2.57	2.81	3.20	3.46	3.69	3.85	4.13
400	571	2.58	2.78	3.12	3.26	3.58	4.04	4.37	4.64	4.83	5.21
450	643	3.21	3.48	3.85	4.05	4.42	5.08	5.39	5.70	5.96	6.38
500	714	3.94	4.23	4.69	4.90	5.33	5.98	6.49	6.82	7.18	7.91
600	857	5.54	5.95	6.61	6.82	7.44	8.27	8.89	9.48	9.83	10.6
700	1000	7.44	7.96	8.71	9.04	9.84	10.9	11.9	12.4	13.0	13.9
800	1140	9.66	10.2	11.1	11.7	12.6	13.9	14.8	15.8	16.4	17.4
900	1285	12.1	12.8	13.8	14.4	15.5	17.1	18.4	19.4	20.2	21.5
1000	1430	14.8	15.6	16.8	17.4	18.7	20.8	22.2	23.3	24.4	26.0
1200	1715	21.0	22.0	23.7	24.5	26.4	28.9	30.7	32.4	33.5	35.9
1400	2000	28.3	29.6	31.8	32.6	35.6	38.2	40.7	42.6	44.3	47.5
1600	2285	36.7	38.4	40.6	42.1	44.5	48.7	51.9	54.1	56.1	59.3
1800	2570	46.1	48.0	50.8	52.3	55.4	60.4	64.5	67.0	69.4	73.5
2000	2860	56.5	58.8	61.9	63.8	67.3	73.4	77.7	81.1	83.8	88.8
2200	3140	67.9	70.2	74.4	76.3	80.5	87.5	92.1	96.8	99.6	105
2400	3430	80.8	83.0	88.0	90.2	94.7	103	108	114	117	123
2600	3710	94.2	97.5	103	105	110	119	125	131	135	142
2800	4000	109	112	118	121	127	136	144	149	155	163
3000	4285	125	129	135	138	145	155	164	170	176	184
3200	4570	142	146	153	156	162	174	184	191	197	208
3400	4860	160	164	172	174	182	196	206	213	220	232
3600	5140	178	183	192	196	204	217	228	237	244	258
3800	5425	199	204	212	217	226	240	251	262	269	285
4000	5715	220	225	234	238	249	265	277	289	295	311
4500	6425	276	284	294	300	311	331	345	358	368	385
5000	7145	341	348	360	365	380	404	418	433	447	466
5500	7855	410	419	433	439	457	480	500	518	532	555
6000	8570	488	498	512	519	540	567	592	609	623	654
6500	9280	573	581	601	609	630	662	686	707	723	755
7000	10000	664	673	692	702	725	763	791	810	829	867
7500	10700	760	773	789	806	827	865	897	925	946	984

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 8 inch (7.981″ inside dia) Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
		26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
		Approx SSU viscosity									
US gal per min	Bbl per hr (42 gal)	125	150	200	300	500	750	1000	1500	2000	3000
50	71.4	*.21*	*.25*	*.34*	*.50*	*.84*	*1.26*	*1.68*	*2.52*	*3.38*	*5.05*
100	143	*.41*	*.50*	*.67*	*1.01*	*1.68*	*2.52*	*3.36*	*5.04*	*6.76*	*10.1*
150	214	1.03	*.75*	*1.01*	*1.51*	*2.52*	*3.78*	*5.04*	*7.56*	*10.1*	*15.1*
200	286	1.67	1.78	*1.34*	*2.02*	*3.37*	*5.04*	*6.72*	*10.1*	*13.5*	*20.2*
250	357	2.46	2.60	2.85	*2.52*	*4.21*	*6.30*	*8.40*	*12.6*	*16.9*	*25.2*
300	429	3.37	3.56	3.89	*3.03*	*5.05*	*7.56*	*10.1*	*15.1*	*20.3*	*30.3*
350	500	4.39	4.63	5.04	5.69	*5.89*	*8.82*	*11.8*	*17.7*	*23.6*	*35.3*
400	571	5.54	5.83	6.35	7.18	*6.73*	*10.1*	*13.5*	*20.2*	*27.0*	*40.4*
450	643	6.79	7.16	7.75	8.76	*7.58*	*11.3*	*15.1*	*22.7*	*30.4*	*45.4*
500	714	8.17	8.58	9.32	10.4	*8.42*	*12.6*	*16.8*	*25.2*	*33.8*	*50.5*
550	786	9.65	10.1	11.0	12.3	*9.26*	*13.9*	*18.5*	*27.8*	*37.2*	*55.5*
600	857	11.2	11.8	12.8	14.3	16.6	*15.1*	*20.2*	*30.3*	*40.5*	*60.6*
700	1000	14.7	15.5	16.7	18.6	21.7	*17.6*	*23.5*	*35.3*	*47.3*	*70.6*
800	1140	18.6	19.4	21.0	23.4	27.1	*20.1*	*26.9*	*40.3*	*54.0*	*80.7*
900	1285	22.9	24.0	25.9	28.7	33.1	37.4	*30.2*	*45.4*	*60.8*	*90.8*
1000	1430	27.4	28.8	31.0	34.4	39.7	44.9	*33.6*	*50.4*	*67.6*	*101*
1200	1715	37.8	39.4	42.8	47.3	54.3	60.9	66.4	*60.5*	*81.0*	*121*
1400	2000	49.7	52.0	56.1	62.0	70.8	79.3	86.7	*70.6*	*94.5*	*141*
1600	2285	63.2	65.7	70.6	78.0	89.3	99.4	108	*80.7*	*108*	*161*
1800	2570	77.9	81.3	86.9	96.2	110	122	132	150	*122*	*182*
2000	2860	93.4	98.0	105	116	132	147	159	180	*135*	*202*
2200	3140	111	116	124	137	155	173	186	211	*149*	*222*
2400	3430	130	135	145	159	181	201	217	244	266	*242*
2600	3710	149	155	168	183	208	231	250	279	306	*262*
2800	4000	170	178	191	210	236	262	283	317	347	*282*
3000	4285	193	201	215	236	267	296	319	357	389	*303*
3200	4570	217	225	240	265	299	332	357	398	433	*323*
3400	4860	242	251	268	294	333	369	397	441	480	*343*
3600	5140	268	284	296	326	369	407	438	488	529	598
3800	5425	296	307	328	359	404	447	482	536	582	656
4000	5715	325	337	358	394	441	488	526	586	635	718
4500	6425	405	417	442	485	543	601	646	718	777	876
5000	7145	488	505	536	582	656	726	776	860	932	
5500	7855	579	605	634	689	773	855	913			
6000	8570	678	706	744	810	910	993				

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 10 inch (10.02″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

For clean steel pipe

Flow		Kinematic viscosity—centistokes									
US gal per min	Bbl per hr (42 gal)	.6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity									
			31.5	33	35	40	50	60	70	80	100
400	571	.83	.92	1.03	1.09	1.19	1.35	1.46	1.55	1.63	1.75
500	714	1.27	1.38	1.53	1.60	1.78	2.00	2.16	2.30	2.40	2.59
600	857	1.78	1.91	2.14	2.24	2.47	2.77	2.98	3.15	3.31	3.54
700	1000	2.39	2.55	2.84	2.97	3.26	3.62	3.93	4.14	4.32	4.67
800	1140	3.06	3.29	3.63	3.79	4.12	4.63	4.99	5.25	5.46	5.86
900	1285	3.84	4.12	4.49	4.72	5.09	5.72	6.14	6.46	6.74	7.19
1000	1430	4.68	4.99	5.42	5.70	6.13	6.90	7.36	7.83	8.10	8.63
1100	1570	5.63	5.97	6.49	6.82	7.34	8.20	8.76	9.25	9.62	10.3
1200	1715	6.61	7.05	7.63	7.85	8 65	9.58	10.3	10.8	11.3	11.9
1300	1855	7.71	8.18	8.85	9.16	9.95	11.0	11.8	12.4	13.0	13.7
1400	2000	8.88	9.42	10.2	10.6	11.4	12.6	13.5	14.2	14.7	15.7
1500	2140	10.1	10.8	11.7	12.0	12.9	14.3	15.3	16.1	16.6	17.8
1600	2285	11.5	12.2	13.2	13.6	14.6	16.0	17.2	18.1	18.7	20.0
1800	2570	14.3	15.1	16.2	16.7	17.9	19.7	20.9	22.1	22.9	24.3
2000	2860	17.8	18.6	19.8	20.6	21.8	24.0	25.5	27.0	28.0	29.5
2200	3140	21.3	22.2	23.7	24.6	26.1	28.6	30.3	32.1	31.8	35.0
2400	3430	25.2	26.3	28.0	28.9	30.7	33.4	35.5	37.3	38.9	41.0
2600	3710	29.6	30.6	32.5	33.5	35.6	38.7	41.0	42.9	44.8	47.3
2800	4000	34.1	35.3	37.4	38.4	40.8	44.5	47.1	49.0	51.0	54.1
3000	4285	39.1	40.2	42.7	43.5	46.6	50.7	53.2	55.7	57.7	61.3
3500	5000	52.5	54.4	57.4	58.9	62.3	66.4	70.6	73.6	76.2	80.8
4000	5715	68.0	70.5	73.9	75.9	79.9	85.8	90.2	94.2	97.1	102
4500	6430	86.1	88.6	92.3	94.8	99.2	107	112	117	120	127
5000	7145	106	109	113	116	122	130	136	142	146	153
5500	7855	128	131	136	139	145	156	162	169	173	182
6000	8570	152	154	161	164	172	183	191	197	204	213
6500	9280	177	180	187	191	201	212	221	228	236	246
7000	10000	205	208	217	220	231	243	255	263	269	282
7500	10700	236	239	248	251	262	277	291	298	303	321
8000	11400	266	272	282	286	296	314	329	337	345	360
8500	12100	301	307	318	321	334	352	367	378	387	403
9000	12900	337	341	354	359	372	392	407	422	429	447
10000	14300	416	422	434	441	453	478	492	511	524	542
11000	15700	503	511	522	533	544	574	593	611	626	649
12000	17150	599	603	617	630	643	679	701	719	737	763

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 10 inch (10.02″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
U S gal per min	Bbl per hr (42 gal)	26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
		Approx SSU viscosity									
		125	150	200	300	500	750	1000	1500	2000	3000
150	214	*.25*	*.30*	*.40*	*.61*	*1.02*	*1.52*	*2.03*	*3.04*	*4.08*	*6.09*
200	286	.58	*.40*	*.54*	*.81*	*1.35*	*2.03*	*2.71*	*4.06*	*5.43*	*8.12*
300	429	1.15	1.22	1.33	*1.22*	*2.03*	*3.04*	*4.06*	*6.09*	*8.15*	*12.2*
400	571	1.88	1.98	2.17	*1.62*	*2.71*	*4.06*	*5.41*	*8.12*	*10.9*	*16.2*
500	714	2.75	2.91	3.18	3.60	*3.39*	*5.07*	*6.77*	*10.1*	*13.6*	*20.3*
600	857	3.78	3.97	4.34	4.89	*4.06*	*6.08*	*8.12*	*12.2*	*16.3*	*24.4*
700	1000	4.94	5.19	5.66	6.37	*4.74*	*7.10*	*9.47*	*14.2*	*19.0*	*28.4*
800	1140	6.21	6.55	7.10	7.97	9.31	*8.12*	*10.8*	*16.2*	*21.7*	*32.5*
900	1285	7.66	8.04	8.71	9.76	11.4	*9.13*	*12.2*	*18.3*	*24.5*	*36.5*
1000	1430	9.21	9.61	10.5	11.7	13.6	*10.1*	*13.5*	*20.3*	*27.2*	*40.6*
1100	1570	10.9	11.4	12.3	13.8	16.0	18.0	*14.9*	*22.3*	*29.9*	*44.6*
1200	1715	12.6	13.4	14.4	16.0	18.6	21.0	*16.2*	*24.4*	*32.6*	*48.7*
1300	1855	14.5	15.4	16.4	18.4	21.2	24.0	*17.6*	*26.4*	*35.3*	*52.8*
1400	2000	16.6	17.5	18.7	20.9	24.1	27.2	*18.9*	*28.4*	*38.0*	*56.8*
1500	2140	18.7	19.6	21.2	23.6	27.2	30.6	33.3	*30.4*	*40.8*	*60.9*
1600	2285	21.0	21.9	23.7	26.3	30.4	34.1	37.2	*32.4*	*43.5*	*64.9*
1800	2570	26.0	27.3	29.2	32.2	37.1	41.7	45.5	*36.5*	*48.9*	*73.1*
2000	2860	31.3	32.7	35.0	38.6	44 4	49.8	54.4	*40.6*	*54.3*	*81.2*
2200	3140	37.0	38.6	41.3	45.8	52.3	58.8	64.0	71.9	*59.8*	*89.3*
2400	3430	43.1	45.1	48.3	53.4	60.9	68.3	74.2	83.8	*65.2*	*97.4*
2600	3710	49.8	52.1	55.4	61.4	70.0	78.3	85.0	96 2	*70.7*	*105*
2800	4000	56.8	59.2	63.5	70.1	79.7	88.9	96.1	109	*76.1*	*114*
3000	4285	64.3	66.8	71.8	78.8	89.8	99.8	108	122	133	*122*
3500	5000	84.9	88.3	94.4	103	117	131	142	159	180	*142*
4000	5715	108	112	119	131	149	165	178	199	217	*162*
4500	6430	133	139	147	162	182	202	218	244	266	300
5000	7145	160	168	179	195	218	241	262	293	318	360
5500	7855	191	199	212	231	258	286	309	345	373	423
6000	8570	223	232	247	268	302	334	359	399	435	489
6500	9280	258	267	286	310	348	384	411	460	499	560
7000	10000	296	305	326	355	396	436	468	522	566	637
7500	10700	335	347	369	402	447	492	529	589	638	766
8000	11400	377	389	414	452	505	550	594	659	710	797
9000	12900	469	482	512	557	624	679	729	809	869	976
10000	14300	567	582	619	666	743	817	872	964		

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 12 inch (12″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

For clean steel pipe

Flow		Kinematic viscosity—centistokes									
		.6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
U S gal per min	Bbl per hr (42 gal)	Approx SSU viscosity									
			31.5	33	35	40	50	60	70	80	100
300	429	.20	.23	.26	.27	.30	.35	.38	.40	.42	.46
400	571	.34	.38	.43	.46	.51	.57	.62	.66	.69	.75
500	714	.51	.56	.64	.68	.75	.85	.96	.97	1.02	1.10
600	857	.73	.79	.89	.95	1.04	1.17	1.26	1.39	1.43	1.50
700	1000	.97	1.05	1.18	1.24	1.37	1.55	1.66	1.75	1.89	1.96
800	1140	1.25	1.35	1.51	1.58	1.75	1.95	2.10	2.22	2.32	2.47
900	1285	1.56	1.69	1.86	1.95	2.16	2.40	2.59	2.74	2.85	3.05
1000	1430	1.91	2.05	2.26	2.35	2.59	2.92	3.13	3.29	3.44	3.68
1200	1715	2.70	2.88	3.13	3.30	3.59	4.04	4.25	4.58	4.74	5.04
1400	2000	3.63	3.85	4.19	4.36	4.76	5.32	5.71	5.98	6.25	6.65
1600	2285	4.68	4.96	5.38	5.57	6.02	6.76	7.24	7.59	7.91	8.39
1800	2570	5.84	6.20	6.73	6.93	7.50	8.31	8.96	9.40	9.65	10.4
2000	2860	7.11	7.56	8.16	8.46	9.11	10.0	10.8	11.4	11.8	12.5
2500	3570	11.0	11.6	12.4	12.8	13.6	14.7	16.0	17.0	17.6	18.5
3000	4285	15.7	16.4	17.5	18.0	19.1	20.0	22.3	23.4	24.4	25.8
3500	5000	21.0	21.9	23.3	24.1	25.6	27.7	29.4	30.8	32.0	34.0
4000	5715	27.2	28.4	30.0	31.0	32.8	35.2	37.4	39.2	40.6	43.2
4500	6430	34.2	35.7	37.8	38.8	40.8	43.8	46.6	48.6	50.2	53.2
5000	7145	42.2	43.8	46.3	47.2	49.7	53.5	56.3	58.8	60.7	64.1
5500	7855	50.7	52.6	55.3	56.4	59.4	64.0	67.0	70.0	72.3	76.1
6000	8570	60.4	62.2	65.3	66.7	70.3	75.2	78.4	82.0	84.7	89.2
6500	9280	70.3	72.4	76.1	77.7	81.4	87.2	90.9	94.6	97.8	103
7000	10000	81.5	83.4	87.7	89.5	93.8	101	105	109	112	118
7500	10700	93.6	95.7	99.9	102	107	114	119	122	127	134
8000	11400	106	108	113	115	120	128	135	139	143	150
9000	12850	134	137	142	145	151	160	167	172	176	186
10000	14300	165	168	174	176	185	195	204	210	215	225
11000	15700	198	203	209	213	223	233	244	251	257	268
12000	17150	236	240	247	252	261	276	286	295	303	314
13000	18550	275	281	290	294	304	321	332	343	351	364
14000	20000	319	326	334	338	351	368	383	395	405	419
15000	21400	366	372	380	386	400	419	436	448	459	476
16000	22850	416	423	432	439	452	474	493	506	519	538
18000	25700	527	535	547	551	568	596	616	632	645	673
20000	28600	646	656	671	676	696	731	751	771	786	816

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 12 inch (12″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
U S gal per min	Bbl per hr (42 gal)	26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
		Approx SSU viscosity									
		125	150	200	300	500	750	1000	1500	2000	3000
100	143	*.08*	*.10*	*.13*	*.20*	*.33*	*.49*	*.66*	*.99*	*1.32*	*1.98*
200	286	*.16*	*.20*	*.26*	*.39*	*.66*	*.99*	*1.32*	*1.97*	*2.64*	*3.95*
300	429	.49	.52	*.39*	*.59*	*.99*	*1.48*	*1.97*	*2.96*	*3.96*	*5.93*
400	571	.80	.85	.93	*.79*	*1.32*	*1.98*	*2.63*	*3.95*	*5.28*	*7.91*
500	714	1.18	1.24	1.36	*.99*	*1.65*	*2.47*	*3.27*	*4.93*	*6.60*	*9.89*
600	857	1.61	1.70	1.86	2.10	*1.98*	*2.96*	*3.95*	*5.92*	*7.93*	*11.9*
700	1000	2.10	2.22	2.42	2.73	*2.30*	*3.45*	*4.61*	*6.90*	*9.25*	*13.8*
800	1140	2.64	2.79	3.04	3.42	*2.63*	*3.95*	*5.26*	*7.89*	*10.6*	*15.8*
900	1285	3.22	3.42	3.72	4.19	4.86	*4.44*	*5.93*	*8.88*	*11.9*	*17.8*
1000	1430	3.88	4.09	4.45	4.99	5.84	*4.93*	*6.58*	*9.87*	*13.2*	*19.8*
1200	1715	5.37	5.60	6.09	6.85	7.94	*5.92*	*7.90*	*11.8*	*15.9*	*23.7*
1400	2000	7.04	7.38	7.94	8.90	10.3	11.7	*9.21*	*13.8*	*18.5*	*27.7*
1600	2285	8.87	9.32	9.99	11.2	12.9	14.7	*10.5*	*15.8*	*21.1*	*31.6*
1800	2570	10.9	11.4	12.5	13.7	15.8	17.8	19.5	*17.7*	*23.8*	*35.6*
2000	2860	13.2	13.8	14.9	16.5	19.0	21.4	23.4	*19.7*	*26.4*	*39.5*
2500	3570	19.7	20.5	21.9	24.2	27.8	31.2	34.0	*24.6*	*33.0*	*49.4*
3000	4285	27.0	28.4	30.3	33.4	38.1	42.8	46.5	52.6	*39.6*	*59.3*
3500	5000	35.9	37.2	39.9	43.8	49.7	55.6	60.4	68.2	73.6	*69.2*
4000	5715	45.4	47.3	50.6	55.4	62.5	70.1	76.1	85.5	93.5	*79.1*
4500	6430	56.2	58.5	62.3	68.2	77.3	85.6	93.0	105	114	*89.0*
5000	7145	67.9	70.7	74.8	82.4	92.9	103	111	125	136	*98.9*
5500	7855	80.6	84.0	88.9	98.2	110	121	131	147	161	181
6000	8570	93.7	98.2	105	114	128	141	152	171	186	210
6500	9280	108	113	121	131	148	162	175	197	213	241
7000	10000	123	129	137	150	168	185	199	223	242	273
7500	10700	140	146	156	168	189	209	223	251	272	306
8000	11400	157	163	175	190	212	235	250	280	304	342
9000	12850	195	202	216	235	262	287	308	343	372	419
10000	14300	235	244	259	283	317	347	372	412	445	499
11000	15700	280	291	307	336	374	410	439	483	525	589
12000	17150	328	339	359	393	436	477	510	562	611	685
13000	18550	381	393	414	455	503	550	590	649	700	787
14000	20000	434	451	476	517	576	630	672	740	794	890
15000	21400	490	510	540	583	653	712	757	836	892	
16000	22850	554	573	605	657	730	797	849	938	999	
18000	25700	689	705	754	807	908	981				
20000	28600	841	861	911	981						

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 14 inch (13.25″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

For clean steel pipe

Flow		Kinematic viscosity—centistokes									
US gal per min	Bbl per hr (42 gal)	.6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity									
			31.5	33	35	40	50	60	70	80	100
400	571	.21	.24	.27	.28	.31	.36	.39	.41	.43	.45
500	714	.32	.35	.40	.43	.47	.53	.58	.61	.64	.69
600	857	.45	.49	.55	.59	.65	.73	.79	.84	.88	.94
700	1000	.60	.65	.73	.77	.85	.96	1.03	1.48	1.15	1.23
800	1140	.77	.83	.94	.98	1.08	1.22	1.31	1.39	1.45	1.55
900	1285	.96	1.04	1.15	1.21	1.34	1.49	1.61	1.70	1.78	1.91
1000	1430	1.17	1.27	1.40	1.47	1.62	1.81	2.71	2.05	2.13	2.30
1200	1715	1.64	1.78	1.95	2.04	2.23	2.51	2.69	2.84	2.95	3.16
1400	2000	2.20	2.36	2.58	2.70	2.94	3.32	3.54	3.73	3.88	4.14
1600	2285	2.83	3.02	3.32	3.45	3.75	4.21	4.51	4.72	4.94	5.23
1800	2570	3.56	3.77	4.12	4.27	4.64	5.19	5.56	5.83	6.07	6.44
2000	2860	4.33	4.60	5.03	5.18	5.64	6.25	6.74	7.07	7.32	7.80
2500	3570	6.67	7.00	7.57	7.91	8.43	9.34	10.0	10.5	10.9	11.6
3000	4285	9.46	9.94	10.7	11.0	11.8	13.0	13.8	14.6	15.2	16.1
3500	5000	12.7	13.4	14.3	14.8	15.7	17.2	18.3	19.1	20.1	21.1
4000	5715	16.6	17.2	18.3	18.9	20.1	21.9	23.3	24.4	25.4	26.9
4500	6430	20.8	21.6	22.8	23.6	25.0	27.0	28.9	30.1	31.3	33.2
5000	7145	25.3	26.7	28.0	28.8	30.5	32.8	35.1	36.6	37.7	40.0
5500	7855	30.7	32.0	33.7	34.4	36.4	39.2	41.5	43.3	45.0	47.5
6000	8570	36.2	37.9	39.8	40.6	42.8	46.1	48.6	50.8	52.7	55.1
6500	9280	42.5	44.1	46.4	47.3	49.9	53.4	56.0	58.9	60.5	63.8
7000	10000	48.9	50.8	53.0	54.5	57.5	61.6	64.2	67.2	69.5	73.2
7500	10700	56.2	57.9	60.4	62.2	65.2	69.9	73.3	76.3	78.9	83.2
8000	11400	63.9	65.4	68.8	70.2	73.6	79.0	82.4	85.8	88.8	93.2
9000	12850	80.2	82.1	86.4	88.3	91.4	98.1	103	106	110	115
10000	14300	99.1	101	106	107	112	120	125	130	133	140
11000	15700	119	122	127	129	135	143	149	154	159	166
12000	17150	141	145	150	154	159	169	176	181	187	194
13000	18550	165	169	175	179	185	196	204	211	215	224
14000	20000	190	196	203	206	214	224	235	242	248	257
15000	21400	218	225	232	235	244	256	268	276	283	293
16000	22850	248	256	261	265	275	289	302	310	318	330
18000	25700	314	321	328	336	346	363	375	388	398	410
20000	28600	387	393	405	412	424	442	457	472	482	500
25000	35700	605	605	624	633	653	676	691	714	733	757

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 14 inch (13.25″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
US gal per min	Bbl per hr (42 gal)	26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
		Approx SSU viscosity									
		125	150	200	300	500	750	1000	1500	2000	3000
200	286	*.11*	*.13*	*.18*	*.27*	*.44*	*.67*	*.89*	*1.33*	*1.78*	*2.66*
300	429	.31	.33	*.27*	*.40*	*.67*	*1.00*	*1.33*	*2.00*	*2.67*	*3.99*
400	571	.50	.53	.58	*.53*	*.89*	*1.33*	*1.77*	*2.66*	*3.56*	*5.32*
500	714	.74	.78	.86	*.67*	*1.11*	*1.66*	*2.22*	*3.33*	*4.45*	*6.65*
600	857	1.01	1.07	1.17	1.31	*1.33*	*1.99*	*2.66*	*3.99*	*5.35*	*7.98*
700	1000	1.31	1.39	1.51	1.71	*1.55*	*2.33*	*3.11*	*4.66*	*6.24*	*9.31*
800	1140	1.66	1.74	1.91	2.14	*1.77*	*2.66*	*3.55*	*5.32*	*7.13*	*10.6*
900	1285	2.03	2.14	2.33	2.62	*2.00*	*2.99*	*3.99*	*5.99*	*8.02*	*12.0*
1000	1430	2.44	2.57	2.80	3.14	3.65	*3.32*	*4.44*	*6.65*	*8.91*	*13.3*
1200	1715	3.36	3.51	3.82	4.29	4.92	*3.99*	*5.32*	*7.99*	*10.7*	*16.0*
1400	2000	4.41	4.60	4.99	5.59	6.65	*4.65*	*6.21*	*9.32*	*12.5*	*18.6*
1600	2285	5.54	5.83	6.28	7.00	8.14	9.19	*7.10*	*10.6*	*14.2*	*21.3*
1800	2570	6.81	7.16	7.70	8.59	9.90	11.2	*7.99*	*12.0*	*16.0*	*23.9*
2000	2860	8.23	8.57	9.30	10.3	11.9	13.4	14.6	*13.3*	*17.8*	*26.6*
2500	3570	12.2	12.8	13.7	15.1	17.5	19.6	21.4	*16.6*	*22.3*	*33.2*
3000	4285	16.9	17.6	18.9	20.9	23.9	26.8	29.2	32.9	*26.7*	*39.9*
3500	5000	22.2	23.2	24.8	27.4	31.2	34.9	37.8	42.9	*31.2*	*46.5*
4000	5715	28.3	29.3	31.5	34.5	39.3	43.8	47.7	53.5	58.4	*53.2*
4500	6430	34.9	36.3	38.9	42.6	48.0	53.7	58.3	65.6	71.8	*59.8*
5000	7145	42.3	43.8	46.7	51.2	58.1	64.6	69.9	78.5	85.7	*66.5*
5500	7855	50.0	52.1	55.3	60.6	68.7	76.1	82.1	92.0	100	*73.1*
6000	8570	58.7	60.9	64.7	70.8	80.1	88.3	95.5	107	117	128
6500	9280	67.6	70.2	74.7	81.8	91.8	101	110	123	134	151
7000	10000	76.9	80.3	85.5	93.4	105	115	125	140	152	171
8000	11400	97.5	102	109	118	133	146	157	175	191	214
9000	12850	120	125	134	146	163	180	192	215	233	262
10000	14300	146	152	162	176	197	216	232	258	280	314
11000	15700	173	180	192	209	233	255	275	304	329	368
12000	17150	204	211	224	245	272	299	320	353	383	429
13000	18550	236	243	258	282	313	343	367	406	439	492
14000	20000	270	279	294	323	357	391	417	462	502	559
15000	21400	305	317	334	365	405	442	472	523	562	629
16000	22850	343	357	377	408	454	497	531	585	628	700
18000	25700	427	440	464	504	560	612	652	721	770	859
20000	28600	521	533	564	601	680	735	786	863	930	

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 16 inch (15.25″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

For clean steel pipe

Flow: U S gal per min	Flow: Bbl per hr (42 gal)	Kinematic viscosity—centistokes: .6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity:	31.5	33	35	40	50	60	70	80	100
600	857	.22	.25	.28	.29	.32	.37	.40	.43	.45	.48
700	1000	.30	.33	.37	.39	.42	.48	.52	.56	.58	.63
800	1140	.38	.42	.47	.49	.53	.61	.66	.71	.74	.80
900	1285	.47	.52	.58	.61	.67	.76	.82	.87	.91	.97
1000	1430	.58	.63	.71	.74	.81	.90	.97	1.04	1.09	1.17
1200	1715	.81	.88	.99	1.03	1.12	1.25	1.36	1.44	1.50	1.61
1400	2000	1.08	1.18	1.31	1.36	1.49	1.64	1.77	1.88	1.97	2.10
1600	2285	1.40	1.51	1.67	1.75	1.88	2.09	2.24	2.38	2.49	2.65
1800	2570	1.76	1.88	2.08	2.16	2.35	2.60	2.74	2.92	3.07	3.27
2000	2860	2.14	2.28	2.50	2.61	2.84	3.15	3.33	3.51	3.68	3.89
2200	3140	2.57	2.72	2.99	3.12	3.38	3.74	3.98	4.16	4.32	4.65
2400	3430	3.04	3.21	3.52	3.67	3.95	4.37	4.65	4.86	4.98	5.42
2600	3710	3.52	3.75	4.08	4.23	4.59	5.05	5.38	5.61	5.84	6.24
2800	4000	4.05	4.32	4.67	4.88	5.26	5.76	6.18	6.44	6.65	7.09
3000	4285	4.61	4.92	5.29	5.53	5.94	6.52	6.99	7.30	7.53	7.97
3500	5000	6.24	6.60	7.07	7.34	7.90	8.64	9.19	9.65	9.98	10.5
4000	5715	8.08	8.51	9.05	9.41	10.1	11.0	11.7	12.3	12.7	13.3
4500	6430	10.2	10.6	11.3	11.7	12.5	13.7	14.5	15.1	15.7	16.6
5000	7145	12.4	12.9	13.8	14.2	15.3	16.6	17.5	18.3	19.0	20.1
6000	8570	17.6	18.3	19.5	20.1	21.3	23.2	24.6	25.5	26.3	28.0
7000	10000	24.4	24.8	26.2	26.8	28.5	30.9	32.5	33.8	34.9	36.8
8000	11400	30.9	32.1	33.8	34.7	36.4	39.6	41.5	43.4	44.6	46.8
9000	12850	38.8	40.3	42.1	43.4	45.2	48.9	51.6	53.8	55.3	58.0
10000	14300	47.9	49.4	51.3	53.2	55.0	59.6	62.6	65.2	67.1	70.1
12000	17150	68.4	70.6	73.3	74.4	78.2	83.6	88.0	91.2	93.9	98.3
14000	20000	92.4	94.6	99.0	101	105	111	117	121	124	130
16000	22850	121	123	128	130	135	143	150	155	159	166
18000	25700	153	155	161	164	170	178	186	193	198	206
20000	28600	189	190	198	201	207	219	226	234	241	250
22500	32200	239	241	248	252	260	275	283	292	298	311
25000	35700	295	297	304	306	318	335	344	353	363	379
27500	39300	356	356	365	371	382	402	413	425	433	451
30000	42850	424	424	431	438	451	472	489	499	509	529
32500	46500	498	498	506	510	530	550	569	581	593	613
35000	50000	577	577	587	591	610	628	656	670	684	707

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 16 inch (15.25″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
		26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
		Approx SSU viscosity									
US gal per min	Bbl per hr (42 gal)	125	150	200	300	500	750	1000	1500	2000	3000
400	571	.26	.28	*.20*	*.30*	*.51*	*.76*	*1.01*	*1.52*	*2.02*	*3.03*
500	714	.38	.40	.44	*.38*	*.63*	*.95*	*1.26*	*1.89*	*2.53*	*3.79*
600	857	.52	.55	.60	*.45*	*.76*	*1.14*	*1.51*	*2.27*	*3.04*	*4.55*
700	1000	.68	.72	.78	.88	*.89*	*1.32*	*1.76*	*2.65*	*3.55*	*5.30*
800	1140	.85	.90	.98	1.11	*1.01*	*1.51*	*2.02*	*3.03*	*4.06*	*6.06*
900	1285	1.04	1.10	1.20	1.35	*1.14*	*1.70*	*2.27*	*3.41*	*4.56*	*6.82*
1000	1430	1.25	1.32	1.44	1.62	*1.26*	*1.89*	*2.52*	*3.79*	*5.07*	*7.57*
1200	1715	1.71	1.81	1.97	2.20	2.57	*2.27*	*3.02*	*4.55*	*6.08*	*9.10*
1400	2000	2.24	2.34	2.56	2.87	3.35	*2.65*	*3.53*	*5.30*	*7.10*	*10.6*
1600	2285	2.84	2.96	3.22	3.45	4.19	*3.03*	*4.03*	*6.06*	*8.11*	*12.1*
1800	2570	3.47	3.65	3.95	4.42	5.13	5.79	*4.54*	*6.82*	*9.12*	*13.6*
2000	2860	4.16	4.39	4.72	5.29	6.12	6.94	*5.04*	*7.58*	*10.1*	*15.1*
2200	3140	4.95	5.16	5.58	6.24	7.21	8.14	8.83	*8.33*	*11.2*	*16.7*
2400	3430	5.58	6.02	6.52	7.25	8.38	9.42	10.3	*9.09*	*12.2*	*18.2*
2600	3710	6.63	6.93	7.49	8.33	9.63	10.8	11.8	*9.85*	*13.2*	*19.7*
2800	4000	7.57	7.92	8.54	9.43	10.9	12.3	13.4	*10.6*	*14.2*	*21.2*
3000	4285	8.55	8.92	9.60	10.6	12.3	13.8	15.0	*11.4*	*15.2*	*22.7*
3500	5000	11.2	11.7	12.6	13.9	16.0	18.0	19.5	22.0	*17.7*	*26.5*
4000	5715	14.1	14.9	15.9	17.6	20.2	22 6	24.5	27.8	*20.3*	*30.3*
4500	6430	17.3	18.1	19.6	21.6	24.7	27.6	29.8	33.8	36.8	*34.1*
5000	7145	20.9	21.9	23.7	26.0	29.5	33.1	36.0	40.4	44.3	*37.9*
6000	8570	29.3	30.2	32.4	35.9	40.8	45.5	49.3	55.3	60.3	*45.5*
7000	10000	38.8	40.1	49.5	47.1	53.4	58.9	63.9	71.9	78.3	88.1
8000	11400	49.2	51.2	53.8	59.6	67.1	74.3	80.6	90.5	98.2	111
9000	12850	60.8	63.2	66.9	72.7	82.8	91.6	98.6	111	120	135
10000	14300	73.5	76.5	81.1	87.5	99.5	110	118	132	144	162
12000	17150	102	106	113	121	137	151	163	181	197	220
14000	20000	136	140	149	160	180	199	214	236	256	287
16000	22850	174	179	189	205	226	251	268	297	322	362
18000	25700	215	222	235	254	280	309	331	366	395	442
20000	28600	261	270	284	306	336	373	398	440	472	529
22500	32200	325	334	351	378	418	460	491	544	582	649
25000	35700	394	405	427	457	507	550	591	650	700	778
27500	39300	468	482	508	545	602	650	699	770	827	915
30000	42850	550	567	597	638	706	757	808	896	960	

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 18 inch (17.182″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

For clean steel pipe

Flow		Kinematic viscosity—centistokes									
		.6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity									
US gal per min	Bbl per hr (42 gal)		31.5	33	35	40	50	60	70	80	100
900	1285	.27	.29	.33	.35	.38	.43	.46	.49	.52	.56
1000	1430	.32	.36	.40	.42	.46	.52	.56	.59	.63	.66
1200	1715	.46	.50	.55	.58	.64	.70	.77	.81	.84	.92
1400	2000	.61	.66	.74	.77	.83	.93	1.01	1.07	1.12	1.20
1600	2285	.77	.85	.94	.98	1.07	1.18	1.27	1.36	1.41	1.51
1800	2570	.96	1.05	1.17	1.22	1.31	1.46	1.56	1.67	1.74	1.85
2000	2860	1.18	1.28	1.41	1.47	1.60	1.77	1.89	2.00	2.10	2.24
2200	3140	1.42	1.53	1.68	1.75	1.89	2.11	2.24	2.36	2.48	2.64
2400	3430	1.68	1.80	1.98	2.06	2.22	2.47	2.62	2.76	2.88	3.07
2600	3710	1.94	2.08	2.29	2.39	2.56	2.85	3.04	3.18	3.29	3.56
2800	4000	2.23	2.40	2.63	2.72	2.95	3.25	3.47	3.62	3.77	4.04
3000	4285	2.55	2.71	3.00	3.11	3.35	3.69	3.39	4.10	4.27	4.55
3500	5000	3.41	3.62	3.98	4.13	4.43	4.89	5.20	5.45	5.61	5.94
4000	5715	4.43	4.69	5.09	5.29	5.69	6.19	6.59	6.96	7.16	7.56
4500	6430	5.56	5.86	6.32	6.57	7.03	7.71	8.17	8.59	8.89	9.31
5000	7145	6.81	7.18	7.70	8.01	8.58	9.36	9.88	10.4	10.8	11.3
5500	7855	8.18	8.56	9.19	9.56	10.2	11.1	11.8	12.3	12.8	13.5
6000	8570	9.66	10.0	10.8	11.2	12.0	13.0	13.8	14.4	14.9	15.8
6500	9280	11.3	11.8	12.6	13.0	13.9	15.1	16.0	16.6	17.2	18.2
7000	10000	13.1	13.6	14.5	14.9	15.9	17.3	18.6	19.1	19.7	20.8
8000	11400	16.9	17.6	18.6	19.2	20.4	22.1	23.4	24.4	25.2	26.4
9000	12850	21.4	22.1	23.3	23.9	25.4	27.6	29.0	30.3	31.2	32.7
10000	14300	26.2	27.0	28.5	29.1	31.0	33.5	35.2	36.6	37.9	39.5
12000	17150	37.4	38.3	40.1	41.3	43.4	46.7	49.4	51.2	52.7	55.1
14000	20000	51.0	52.2	54.2	55.0	57.9	62.4	65.6	68.1	70.1	73.4
16000	22850	66.0	67.6	70.3	71.4	74.6	79.9	84.1	87.3	89.5	93.7
18000	25700	83.6	84.9	88.3	89.6	93.0	99.7	105	109	111	116
20000	28600	102	105	108	110	114	121	127	132	136	141
22000	31400	123	126	130	132	136	145	151	156	161	168
24000	34300	146	150	153	156	161	170	179	185	189	198
26000	37100	170	176	180	181	188	198	207	214	219	229
28000	40000	197	202	207	209	217	228	237	245	251	263
30000	42850	227	232	238	240	247	260	270	279	286	298
35000	50000	308	313	321	324	334	349	362	370	380	395
40000	57150	403	406	416	423	429	446	466	476	489	509

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 18 inch (17.182″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow: U S gal per min	Flow: Bbl per hr (42 gal)	Kinematic viscosity—centistokes: 26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
		Approx SSU viscosity: 125	150	200	300	500	750	1000	1500	2000	3000
800	1140	.49	.51	.56	.63	*.63*	*.94*	*1.25*	*1.88*	*2.51*	*3.76*
900	1285	.59	.63	.68	.78	*.71*	*1.05*	*1.41*	*2.11*	*2.83*	*4.22*
1000	1430	.71	.75	.82	.93	*.78*	*1.17*	*1.56*	*2.35*	*3.14*	*4.70*
1200	1715	.98	1.02	1.12	1.26	*.94*	*1.41*	*1.88*	*2.82*	*3.77*	*5.63*
1400	2000	1.27	1.34	1.46	1.64	1.92	*1.64*	*2.19*	*3.28*	*4.40*	*6.57*
1600	2285	1.61	1.68	1.84	2.07	2.40	*1.88*	*2.50*	*3.75*	*5.03*	*7.51*
1800	2570	1.98	2.07	2.25	2.53	2.93	*2.11*	*2.82*	*4.22*	*5.66*	*8.45*
2000	2860	2.37	2.50	2.70	3.02	3.51	3.96	*3.13*	*4.70*	*6.29*	*9.39*
2200	3140	2.80	2.95	3.17	3.55	4.12	4.66	*3.44*	*5.16*	*6.91*	*10.3*
2400	3430	3.27	3.43	3.69	4.13	4.77	5.40	*3.75*	*5.63*	*7.55*	*11.3*
2600	3710	3.77	3.92	4.26	4.75	5.48	6.17	6.74	*6.10*	*8.17*	*12.2*
2800	4000	4.29	4.48	4.88	5.40	6.25	7.01	7.66	*6.67*	*8.80*	*13.1*
3000	4285	4.85	5.07	5.47	6.07	7.02	7.90	8.61	*7.04*	*9.43*	*14.1*
3500	5000	6.37	6.65	7.13	7.90	9.12	10.2	11.1	*8.21*	*11.0*	*16.4*
4000	5715	7.99	8.42	9.05	10.0	11.5	12.9	14.0	15.8	*12.6*	*18.8*
4500	6430	9.81	10.4	11.0	12.3	14.1	15.8	17.1	19.4	*14.1*	*21.1*
5000	7145	11.9	12.4	14.4	14.8	16.9	18.9	20.5	23.1	25.2	*23.5*
5500	7855	14.0	14.7	15.9	17.4	19.8	22.2	24.2	27.2	29.7	*25.8*
6000	8570	16.5	17.2	18.5	20.4	23.1	25.8	28.1	31.6	34.5	*28.2*
6500	9280	19.1	19.8	21.2	23.5	26.6	29.7	32.2	36.1	39.5	*30.5*
7000	10000	27.9	22.5	24.1	26.7	30.4	33.8	36.5	41.0	44.6	*32.8*
8000	11400	27.8	28.8	30.5	33.8	38.2	42.2	45.9	51.7	56.2	63.4
9000	12850	34.4	35.7	37.6	41.6	46.8	51.9	56.3	63.2	68.6	77.5
10000	14300	41.4	43.3	45.6	49.7	56.6	62.6	67.4	75.5	82.2	92.6
12000	17150	57.8	59.9	63.5	68.6	77.9	85.9	92.3	103	112	126
14000	20000	76.2	79.1	84.0	90.1	102	113	122	135	146	164
16000	22850	97.4	101	107	116	129	143	153	169	184	207
18000	25700	121	125	131	143	158	175	187	208	226	253
20000	28600	147	151	160	173	191	211	226	250	270	302
22000	31400	181	186	190	205	227	250	268	296	317	355
24000	34300	205	212	223	240	264	290	312	344	369	413
26000	37100	238	245	257	277	307	332	359	395	426	475
28000	40000	272	280	295	316	350	380	409	450	486	541
30000	42850	309	318	335	359	397	429	462	509	549	607
35000	50000	413	423	443	474	525	563	601	668	713	790

Loss in lb per sq in = .433 (sp gr) (figures in table)

3

Friction Losses in Pipe; 20 inch (19.182″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

For clean steel pipe

Flow		Kinematic viscosity—centistokes									
		.6	1.1	2.1	2.7	4.3	7.4	10.3	13.1	15.7	20.6
		Approx SSU viscosity									
U S gal per min	Bbl per hr (42 gal)		31.5	33	35	40	50	60	70	80	100
1000	1430	.19	.21	.23	.25	.27	.31	.33	.35	.37	.40
1500	2140	.40	.44	.50	.54	.56	.62	.68	.72	.75	.80
2000	2860	.69	.74	.83	.86	.94	1.04	1.11	1.19	1.24	1.32
3000	4285	1.48	1.59	1.74	1.81	2.00	2.17	2.32	2.42	2.52	2.71
4000	5715	2.57	2.71	2.96	3.09	3.30	3.65	3.90	4.09	4.21	4.45
5000	7145	3.93	4.14	4.47	4.65	4.98	5.49	5.82	6.12	6.36	6.63
6000	8670	5.57	5.88	6.26	6.52	7.00	7.65	8.12	8.47	8.81	9.29
7000	10000	7.47	7.88	8.41	8.70	9.29	10.1	10.8	11.2	11.6	12.3
8000	11400	9.75	10.2	10.8	11.1	11.8	13.0	13.8	14.3	14.8	15.6
9000	12850	12.3	12.8	13.5	13.9	14.8	16.0	17.0	17.8	18.3	19.3
10000	14300	15.0	15.6	16.4	16.9	18.0	19.6	20.5	21.5	22.2	23.3
11000	15700	18.0	18.7	19.8	20.2	21.5	23.4	24.5	25.6	26.4	27.7
12000	17150	21.4	22.1	23.3	23.9	25.2	27.3	28.7	29.9	30.9	32.5
13000	18550	24.9	25.8	27.2	27.8	29.2	31.6	33.3	34.7	35.9	37.5
14000	20000	28.7	29.9	31.3	32.0	33.6	36.2	38.3	39.8	40.9	43.0
15000	21400	32.9	34.0	35.9	36.7	37.8	41.3	43.5	45.1	46.4	48.9
16000	22850	37.5	38.7	40.6	41.5	43.3	46.7	48.8	50.7	52.2	55.0
18000	25700	47.0	48.6	50.9	52.1	54.0	57.9	60.7	63.0	64.9	68.0
20000	28600	58.1	59.5	62.4	63.8	65.8	70.6	73.9	76.8	78.7	82.1
22000	31400	70.3	72.0	74.9	76.7	79.0	84.2	88.3	91.2	94.1	98.2
24000	34300	83.6	85.0	88.5	90.6	93.3	98.8	104	107	111	115
26000	37100	97.3	99.0	103	106	109	115	120	124	128	133
28000	40000	113	115	120	121	126	133	138	143	147	153
30000	42850	130	132	136	138	144	151	157	162	166	174
32000	45700	148	149	155	156	162	171	177	183	188	195
34000	48600	167	168	173	176	182	191	198	205	211	219
36000	51400	187	188	194	198	204	213	221	227	233	244
38000	54300	208	210	215	218	225	237	244	251	258	269
40000	57150	230	232	238	242	250	261	269	276	284	296
42000	60000	252	256	263	265	273	286	294	303	311	324
44000	62900	277	279	286	290	300	314	323	330	339	353
46000	65700	302	305	312	317	325	340	350	361	368	383
48000	68600	329	332	337	343	354	371	382	390	398	415
50000	71450	357	360	366	372	381	399	411	420	429	447
55000	78600	432	436	443	447	461	479	494	505	516	534

Loss in lb per sq in = .433 (sp gr) (figures in table)

Friction Losses in Pipe; 20 inch (19.182″ inside dia)
Loss in ft of liquid per 1000 ft of pipe

Figures for clean steel pipe, except those in italics which are for any pipe.

Flow		Kinematic viscosity—centistokes									
		26.4	32.0	43.2	65.0	108.4	162.3	216.5	325	435	650
		Approx SSU viscosity									
US gal per min	Bbl per hr (42 gal)	125	150	200	300	500	750	1000	1500	2000	3000
800	1140	.29	.30	.33	*.24*	*.41*	*.61*	*.81*	*1.21*	*1.62*	*2.42*
900	1285	.35	.37	.41	.46	*.46*	*.68*	*.91*	*1.37*	*1.83*	*2.73*
1000	1430	.42	.45	.49	.55	*.51*	*.76*	*1.01*	*1.52*	*2.03*	*3.03*
1500	2140	.85	.90	.98	1.10	1.28	*1.14*	*1.52*	*2.28*	*3.05*	*4.55*
2000	2860	1.41	1.47	1.61	1.81	2.08	*1.52*	*2.02*	*3.03*	*4.06*	*6.06*
3000	4285	2.87	2.99	3.24	3.62	4.18	4.69	5.13	*4.55*	*6.10*	*9.10*
4000	5715	4.76	4.97	5.34	5.91	6.84	7.66	8.33	*6.07*	*8.12*	*12.1*
5000	7145	6.99	7.38	7.92	8.79	10.1	11.3	12.2	13.8	*10.1*	*15.2*
6000	8670	9.72	10.1	11.0	12.0	13.7	15.4	16.7	18.8	20.5	*18.2*
7000	10000	12.8	13.3	14.4	15.8	17.9	20.1	21.8	24.5	26.8	*21.2*
8000	11400	16.4	16.9	18.0	20.0	22.7	25.3	27.3	30.6	33.4	*24.2*
9000	12850	20.3	21.0	22.3	24.3	27.9	30.8	33.4	37.6	40.9	46.2
10000	14300	24.5	25.4	26.9	29.6	33.4	37.0	40.2	45.1	49.0	55.3
11000	15700	29.0	30.2	31.9	34.9	39.6	43.9	47.2	53.1	57.5	64.9
12000	17150	34.0	35.4	37.3	40.4	46.1	51.2	54.8	61.5	66.9	75.2
13000	18600	39.3	40.8	43.2	46.9	53.1	58.8	62.9	70.6	76.7	86.2
14000	20000	44.9	46.6	49.6	53.4	60.7	66.8	71.7	80.2	87.3	98.1
15000	21400	50.8	52.7	56.2	60.5	68.6	75.1	81.0	90.5	98.3	110
16000	22850	57.1	59.3	63.0	67.9	76.8	84.5	90.9	101	109	123
18000	25700	71.2	73.5	77.8	84.0	94.1	104	112	123	134	151
20000	28600	86.4	88.8	94.1	102	112	125	133	148	160	181
22000	31400	102	106	112	121	134	148	159	175	189	213
24000	34300	120	124	131	142	156	173	185	205	219	246
26000	37100	139	144	151	164	180	198	212	235	252	282
28000	40000	159	164	173	186	206	234	243	267	287	321
30000	42850	180	186	197	212	234	253	274	300	325	362
32000	45700	203	210	221	238	263	285	307	338	364	404
34000	48600	228	234	247	266	294	318	341	376	405	447
36000	51400	254	260	274	296	327	352	376	415	446	493
38000	54300	279	288	302	326	360	386	412	458	494	541
40000	57150	307	315	332	357	394	424	449	499	534	591
42000	60000	337	345	364	390	430	464	491	546	584	646
44000	62900	367	376	395	425	467	504	534	595	634	702
47000	67100	414	427	445	480	522	570	602	665	713	787
50000	71450	462	477	501	537	588	639	672	741	795	879

Loss in lb per sq in = .433 (sp gr) (figures in table)

Weights and Volumes of Liquid Paper Pulp Stock in U S Gallons

Air Dry Stock

% or lb dry stock to 100 lb liquid	Lb dry stock in 1 cu ft liquid	No cu ft containing 1 lb stock	Lb dry stock in 1 gal. liquid	No gal containing 1 lb stock	Cu ft liquid per min per ton dry stock per 24 hours	Gal liquid per min per ton dry stock per 24 hours	Lb liquid per min per ton dry stock per 24 hours	Lb water per lb stock	Gal water per lb stock	Gal water per ton stock
.10	.0625	16.00	.008	119.55	22.22	**166.20**	1388.88	999.00	119.00	238710
.20	.1250	8.00	.017	59.77	11.11	**83.10**	694.44	499.	59.50	119996
.25	.1562	6.40	.021	47.87	8.88	**66.49**	555.55	399.	47.75	95511
.30	.1875	5.33	.025	39.90	7.41	**55.41**	462.96	33.323	39.78	79553
.33	.2063	4.80	.028	35.91	6.66	**49.86**	416.64	297.10	35.55	71094
.35	.2187	4.57	.029	34.20	6.35	**47.50**	396.83	284.71	34.08	68154
.40	.2500	4.00	.033	29.92	5.55	**41.56**	347.22	249.	29.80	59605
.45	.2812	3.66	.038	27.43	4.94	**36.94**	308.64	221.22	28.48	52955
.50	.3125	3.20	.042	23.92	4.44	**33.25**	277.77	199.	23.82	47636
.55	.3437	2.91	.046	21.76	4.04	**30.22**	252.52	190.82	21.64	43284
.60	.3750	2.66	.050	19.94	3.70	**27.71**	231.48	165.66	19.83	39656
.65	.4062	2.46	.054	18.41	3.42	**25.57**	213.68	152.85	18.29	36569
.70	.4375	2.28	.058	17.10	3.17	**23.75**	198.42	141.86	16.98	33957
75	.4687	2.13	.063	15.96	2.96	**22.16**	185.18	132.33	15.84	31678
80	.5000	2.00	.067	14.96	2.78	**20.78**	173.61	124.	14.84	29683
.85	.5312	1.88	.071	14.06	2.61	**19.50**	163.50	116.65	13.96	27922
.90	.5624	1.83	.075	13.71	2.47	**18.47**	154.32	110.11	13.18	26358
.95	.5937	1.68	.079	12.61	2.34	**17.50**	146.19	104.26	12.48	24958
1.00	.6250	1.60	.084	11.97	2.22	**16.62**	138.88	99.	11.85	23398
1.25	.7812	1.28	.104	9.57	1.78	**13.30**	111.11	79.	9.45	18911
1.50	.9375	1.07	.125	7.98	1.48	**11.08**	92.59	66.66	7.86	15719
1.75	1.0937	.91	.146	6.84	1.27	**9.50**	79.37	56.14	6.72	13439
2.00	1.2500	.80	.167	5.97	1.11	**8.31**	69.44	49.	5.86	11729
2.25	1.4062	.73	.188	5.49	.99	**7.39**	61.73	43.44	5.20	10399
2.50	1.5625	.64	.209	4.79	.89	**6.65**	55.55	39.	4.67	9335
2.75	1.7187	.58	.230	4.35	.81	**6.04**	50.50	35.36	4.23	8465
3.00	1.8750	.53	.251	3.99	.74	**5.54**	46.29	32.33	3.87	7740
3.50	2.1875	.46	.292	3.42	.63	**4.75**	39.68	27.57	3.30	6600
4.00	2.5000	.40	.334	2.99	.55	**4.15**	34.72	24.	2.87	5745
4.50	2.8125	.36	.376	2.66	.49	**3.69**	30.86	21.22	2.54	5080
5.00	3.1250	.32	.418	2.39	.44	**3.32**	27.77	19.	2.27	4536
5.50	3.4375	.29	.459	2.18	.40	**3.02**	25.25	17.18	2.06	4113
6.00	3.7500	.27	.501	1.99	.37	**2.77**	23.15	15.66	1.87	3750
6.50	4.0600	.25	.543	1.84	.343	**2.57**	21.40	14.4	1.72	3460
7.00	4.3700	.23	.585	1.71	.318	**2.38**	19.80	13.3	1.59	3190
7.50	4.6700	.21	.625	1.60	.297	**2.22**	18.50	12.3	1.48	2960
8.00	4.9800	.20	.666	1.50	.278	**2.08**	17.40	11.5	1.38	2760

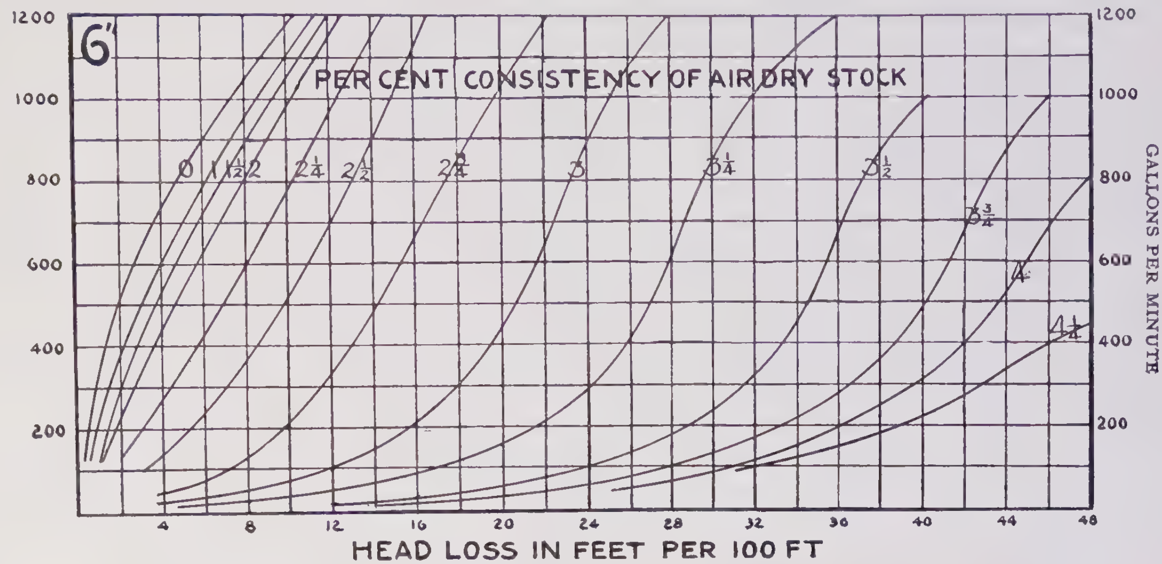
Note:—For conversion: 1% bone dry stock = 1.1% air dry stock.
Tons of air dry stock per 24 hours = gpm × C × 6
C=% consistency as a decimal (1.5% stock; C=.015)

Friction of Ground Wood Paper Pulp Stock in 6″ Cast Iron or Spiral Riveted Pipe

Curved lines show % consistency of air dry ground wood stock

Increase friction 10% if kraft, sulphite o. soda stock

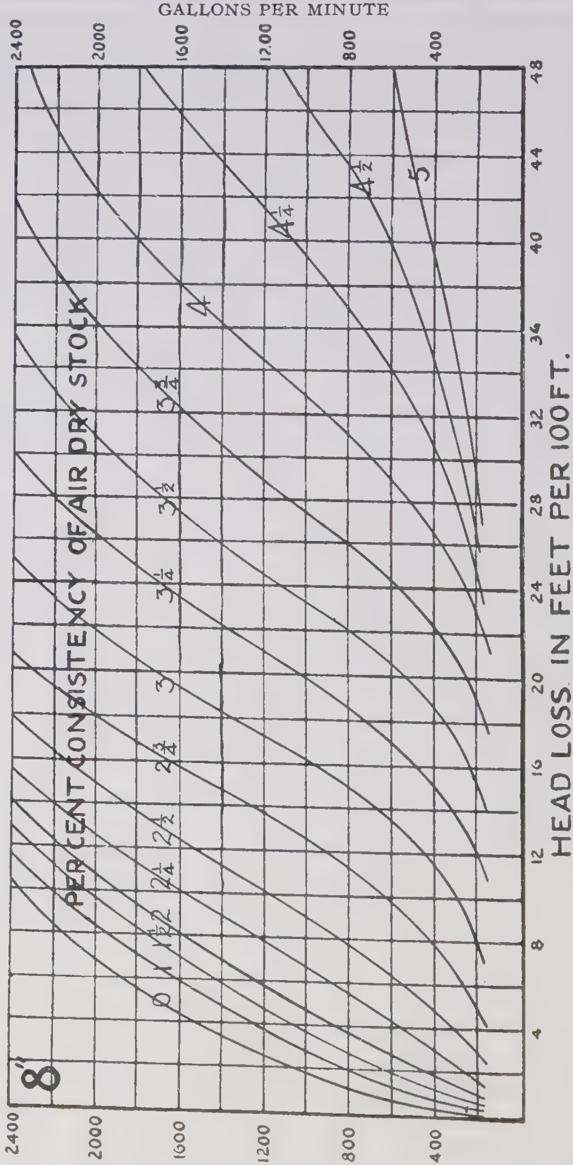
Reduce friction 20% if wood stave pipe



Friction of Ground Wood Paper Pulp Stock in 8″ Cast Iron or Spiral Riveted Pipe

Curved lines show % consistency air dry ground wood stock

Increase friction 10% if kraft, sulphite or soda stock   Reduce friction 20% if wood stave pipe

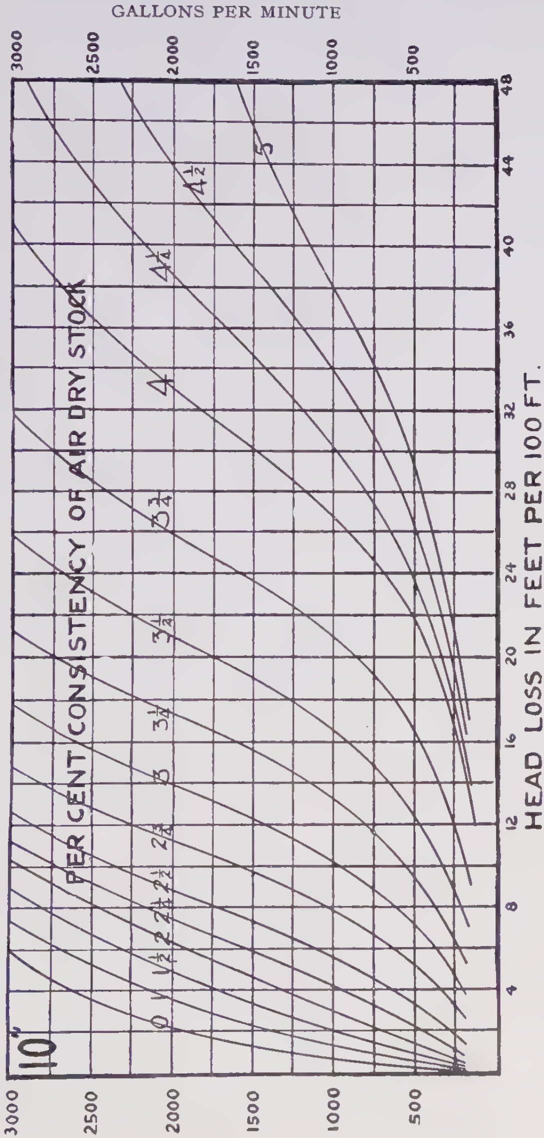


Friction of Ground Wood Paper Pulp Stock in 10″ Cast Iron or Spiral Riveted Pipe

Curved lines show % consistency air dry ground wood stock

Increase friction 10% if kraft, sulphite or soda stock

Reduce friction 20% if wood stave pipe

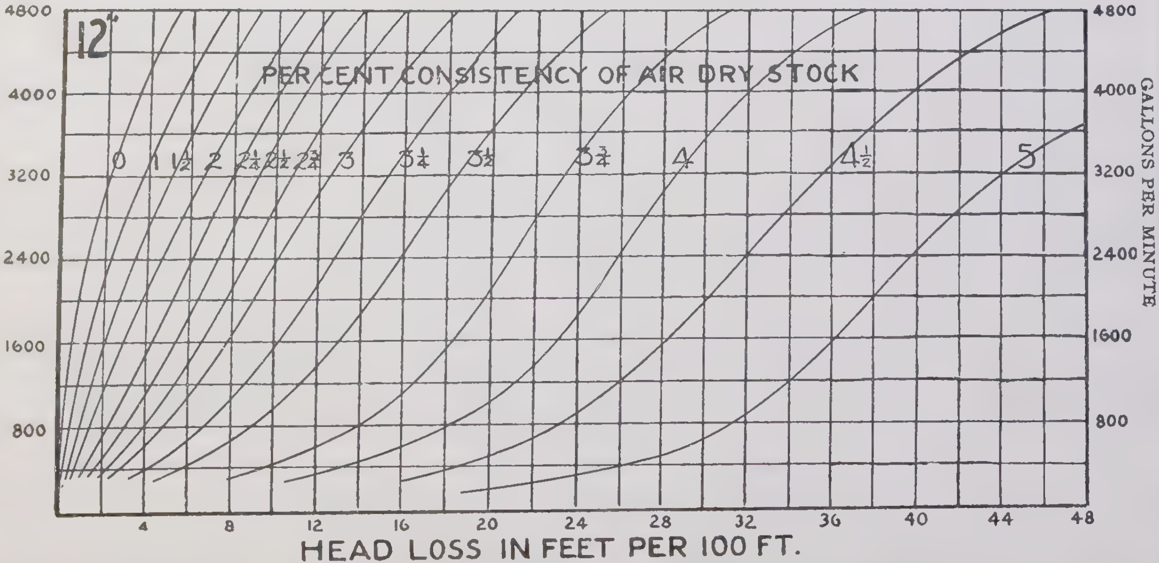


Friction of Ground Wood Paper Pulp Stock in 12″ Cast Iron or Spiral Riveted Pipe

Curved lines show % consistency air dry ground wood stock

Increase friction 10% if kraft, sulphite or soda stock

Reduce friction 20% if wood stave pipe

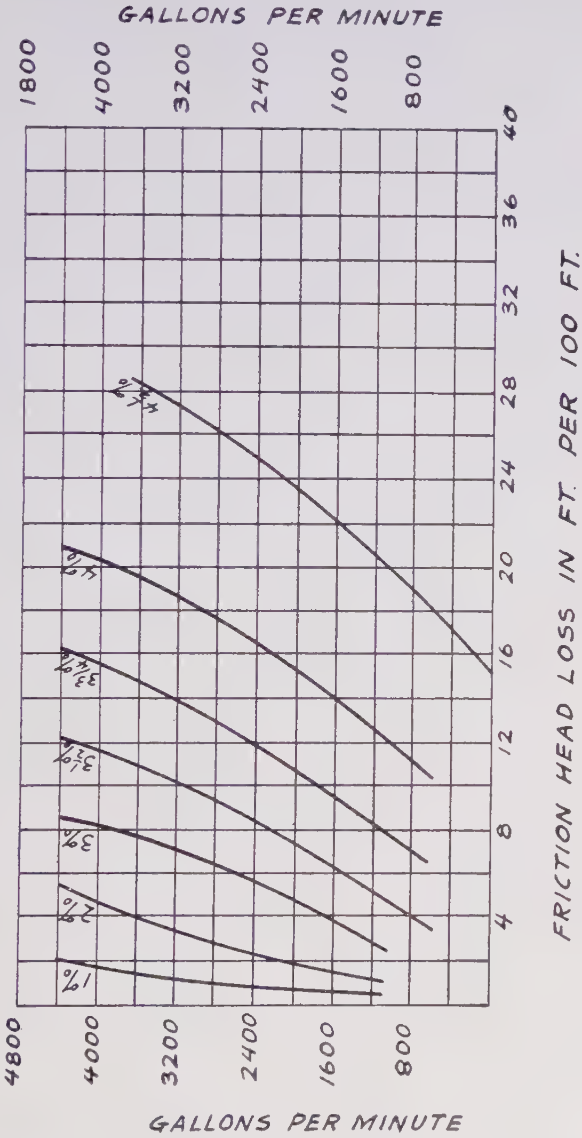


Friction of Ground Wood Paper Pulp Stock in 16″ Cast Iron or Spiral Riveted Pipe

Curved lines show % consistency of air dry ground wood stock

Increase friction 10% if kraft, sulphite or soda stock

Reduce friction 20% if wood stave pipe



3

Physical Properties of Calcium Chloride ($CaCl_2$) and Sodium Chloride (NaCl)

CALCIUM CHLORIDE						SODIUM CHLORIDE					
Degrees Baume 60°F	Specific gravity 60°/60/F	Degrees Salometer 60°F	%$CaCl_2$ by weight	NOTE	Freezing point °F	Specific gravity 60°/60°F	Degrees Baume 60° F	Degrees Salometer 60° F	% NaCl by weight	Lb NaCl per gallon solution	Freezing point °F
0	1.000	0	0	Commercial Ca Cl^{2} is available in several degrees of hydration. It also picks up moisture from the atmosphere. Solutions should, therefore, be made by reference to hydrometer reading.	32.	1.000	0	0	0	0	32.0
1.	1.007	4	1		31.1	1.007	1.04	3.8	1	0.084	30.5
2.1	1.015	8	2		30.4	1.015	2.07	7.6	2	0.169	29.3
3.4	1.024	12	3		29.5	1.022	3.08	11.4	3	0.256	27.8
4.5	1.032	16	4		28.6	*1.029	4.08	15 2	4	0.344	26.6
5.7	1.041	22	5		27.7	1.036	5.07	18.9	5	0.433	25.2
6.8	1.049	26	6		26.6	1.044	6.07	22.7	6	0.523	23.9
8.	1.058	32	7		25.5	1.051	7.06	26.5	7	0.617	22.5
9.1	1.067	36	8		24.3	1.059	8.01	30 3	8	0.708	21.2
10.2	1.076	40	9		22.8	1.066	8.97	33.9	9	0.802	19.9
11.4	1.085	44	10		21.3	1.073	9.90	37.5	10	0.897	18.7
12.5	1.094	48	11		19.7	1.081	10.86	41.3	11	0.994	17.4
13.5	1.103	52	12		18.1	1.089	11.80	45.2	12	1.092	16.0
14.6	1.112	58	13		16.3	1.096	12.73	49.2	13	1.190	14.7
15.6	1 121	62	14		14.3	1.104	13.64	53.0	14	1.289	13.
16.8	1.131	68	15		12.2	1.111	14.54	56.8	15	1.389	12.2
17.8	1.140	72	16		10.	1.119	15.46	60.6	16	1.495	11.0
19.	1.151	76	17		7.5	1.127	16.37	64.4	17	1.602	9.8
20.	1.160	80	18		4.6	1.135	17.27	68.2	18	1.710	8 5
21.	1.169	84	19		1.7	1.143	18.16	71.9	19	1.819	7.3
22.	1.179	88	20		—1.4	1.151	19.03	75.5	20	1.928	6.1
23.	1.188	92	21		—4.9	1.159	19.92	79.1	21	2.037	5.0
24.	1.198	96	22		—8.6	1.168	20.80	83.0	22	2.147	3.9
25.	1.208	100	23		—11.6	1.176	21.68	86.9	23	2.266	2.8
26.	1.218	104	24		—17.1	1.184	22.54	90.9	24	2.376	1.7
27.	1.229	108	25		—21.8	1.192	23.39	94.7	25	2.488	+0.5
28.	1.239	112	26		—27.	1.201	24.27	98.5	26	2.610	—1.1
29.	1.250	116	27		—32.6	1.204	24.60	100.	26 395	2 661	—1.6
30.	1.261	120	28		—39.2						
31.	1.272	124	29		—46.2						
32.	1.283	128	30		—54.4						

Temperature correction 1° Salometer for every 7½°F added to reading for temperatures above 60°F; subtracted below.
*Specific gravity of sea water.

Specific Gravity of Caustic Soda Solutions 15°C (59°F) by Lunge

Specific gravity	Degrees Baumé	Degrees Twaddell	Per cent NaOH	Per cent Na^2O	One gallon contains pounds NaOH	One gallon contains pounds Na^2O
1.007	1.0	1.4	0.61	0.47	0.051	0.039
1.014	2.0	2.8	1.20	0.93	0.101	0.079
1.022	3.1	4.4	2.00	1.55	0.170	0.132
1.029	4.1	5.8	2.70	2.10	0.232	0.180
1.036	5.1	7.2	3.35	2.60	0.289	0.225
1.045	6.2	9.0	4.00	3.10	0.345	0.268
1.052	7.2	10.4	4.64	3.60	0.407	0.316
1.060	8.2	12.0	5.29	4.10	0.467	0.362
1.067	9.1	13.4	5.87	4.55	0.522	0.405
1.075	10.1	15.0	6.55	5.08	0.587	0.455
1.083	11.1	16.6	7.31	5.67	0.660	0.512
1.091	12.1	18.2	8.00	6.20	0.728	0.564
1.100	13.2	20.0	8.68	6.73	0.796	0.617
1.108	14.1	21.6	9.42	7.30	0.870	0.674
1.116	15.1	23.2	10.06	7.80	0.936	0.726
1.125	16.1	25.0	10.97	8.50	1.029	0.797
1.134	17.1	26.8	11.84	9.18	1.119	0.868
1.142	18.0	28.4	12.64	9.80	1.203	0.933
1.152	19.1	30.4	13.55	10.50	1.301	1.008
1.162	20.2	32.4	14.37	11.14	1.392	1.079
1.171	21.2	34.2	15.13	11.73	1.477	1.145
1.180	22.1	36.0	15.91	12.33	1.565	1 213
1.190	23.1	38.0	16.77	13.00	1.664	1.290
1.200	24.2	40.0	17.67	13.70	1.768	1.371
1.210	25.2	42.0	18.58	14.40	1.874	1.453
1.220	26.1	44.0	19.58	15.18	1.992	1.554
1.231	27.2	46.2	20.59	15.96	2.113	1.638
1.241	28.2	48.2	21.42	16.76	2.216	1.734
1.252	29.2	50.4	22.64	17.55	2.363	1.832
1.263	30.2	52.6	23.67	18.35	2.492	1.932
1.274	31.2	54.8	24.81	19.23	2.635	2.042
1.285	32.2	57.0	25.80	20.00	2.764	2.143
1.297	33.2	59.4	26.83	20.80	2.901	2.249
1.308	34.1	61.6	27.80	21.55	3.032	2.350
1.320	35.2	64.0	28.83	22.35	3.173	2.460
1.332	36.1	66.4	29 93	23.20	3.324	2.576
1.345	37.2	69.0	31.22	24.20	3.501	2.714
1.357	38.1	71.4	32.47	25 17	3.673	2.848
1.370	39.2	74.0	33.69	26.12	3.848	2.983
1.383	40.2	76.6	34.96	27.10	4.031	3 125
1.397	41.2	79.4	36.25	28.10	4.222	3.273
1.410	42.2	82 0	37.47	29 05	4.405	3.415
1.424	43.2	84 8	38.80	30.08	4.606	3.571
1.438	44.2	87.6	39.99	31.00	4.794	3.716
1.453	45.2	90.6	41.41	32.10	5.016	3.888
1.468	46.2	93.6	42.83	33.20	5.242	4.063
1.483	47.2	96.6	44.38	34.40	5.487	4.253
1.498	48.2	99.6	46.15	35.70	5.764	4.459
1.514	49.2	102.8	47.60	36.90	6.008	4.658
1.530	50.2	106.0	49.02	38.00	6.253	4.847

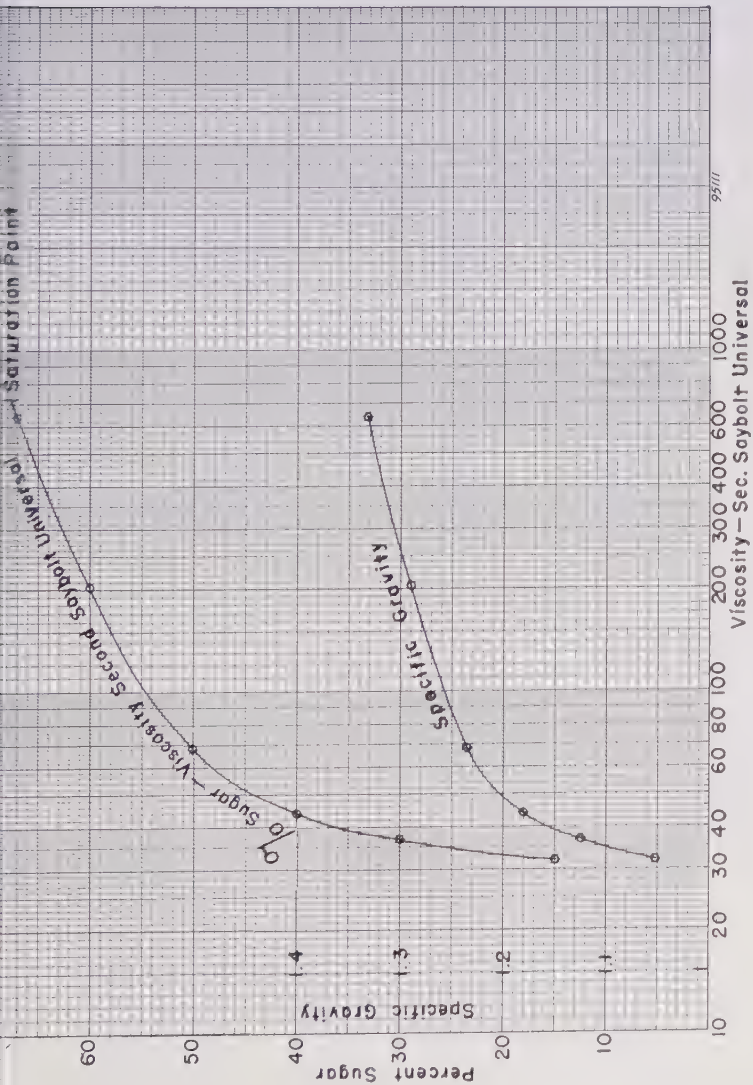
Table of Degrees Brix

Per Cent Sugar (Degrees Balling's or Brix) with Corresponding Specific Gravity and Degrees Baume. Temperature 60° F

Per cent sugar Balling's or Brix 60°F—15.56°C	Specific gravity 60°/60°F	Degrees Baume 60°F	Per Cent sugar Balling's or Brix 60°F—15.56°C	Specific gravity 60°/60°F	Degrees Baume 60°F	Per cent sugar Balling's or Brix 60°F—15.56°C	Specific gravity 60°/60°F	Degrees Baume 60°F
0	1.0000	0.00	34	1.1491	18.81	68	1.3384	36.67
1	1.0039	0.56	35	1.1541	19.36	69	1.3447	37.17
2	1.0078	1.13	36	1.1591	19.90	70	1.3509	37.66
3	1.0118	1.68	37	1.1641	20.44	71	1.3573	38.17
4	1.0157	2.24	38	1.1692	20.98	72	1.3636	38.66
5	1.0197	2.80	39	1.1743	21.52	73	1.3700	39.16
6	1.0238	3.37	40	1.1794	22.06	74	1.3764	39.65
7	1.0278	3.93	41	1.1846	22.60	75	1.3829	40.15
8	1.0319	4.49	42	1.1898	23.13	76	1.3894	40.64
9	1.0360	5.04	43	1.1950	23.66	77	1.3959	41.12
10	1.0402	5.60	44	1.2003	24.20	78	1.4025	41.61
11	1.0443	6.15	45	1.2057	24.74	79	1.4091	42.10
12	1.0485	6.71	46	1.2110	25.26	80	1.4157	42.58
13	1.0528	7.28	47	1.2164	25.80	81	1.4224	43.06
14	1.0570	7.81	48	1.2218	26.32	82	1.4291	43.54
15	1.0613	8.38	49	1.2273	26.86	83	1.4359	44.02
16	1.0657	8.94	50	1.2328	27.38	84	1.4427	44.49
17	1.0700	9.49	51	1.2384	27.91	85	1.4495	44.96
18	1.0744	10.04	52	1.2439	28.43	86	1.4564	45.44
19	1.0788	10.59	53	1.2496	28.96	87	1.4633	45.91
20	1.0833	11.15	54	1.2552	29.48	88	1.4702	46.37
21	1.0878	11.70	55	1.2609	30.00	89	1.4772	46.84
22	1.0923	12.25	56	1.2667	30.53	90	1.4842	47.31
23	1.0968	12.80	57	1.2724	31.05	91	1.4913	47.77
24	1.1014	13.35	58	1.2782	31.56	92	1.4984	48.23
25	1.1060	13.90	59	1.2841	32.08	93	1.5055	48.69
26	1.1107	14.45	60	1.2900	32.60	94	1.5126	49.14
27	1.1154	15.00	61	1.2959	33.11	95	1.5198	49.59
28	1.1201	15.54	62	1.3019	33.63	96	1.5270	50.04
29	1.1248	16.19	63	1.3079	34.13	97	1.5343	50.49
30	1.1296	16.63	64	1.3139	34.64	98	1.5416	50.94
31	1.1345	17.19	65	1.3200	35.15	99	1.5489	51.39
32	1.1393	17.73	66	1.3261	35.66	100	1.5563	51.93
33	1.1442	18.28	67	1.3323	36.16			

The above table is from the determinations of Dr. F. Plato, and has been adopted as standard by the United States Bureau of Standards.

Specific Gravity - Viscosity Curves for Sugar



CHAPTER IV

STEAM DATA

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STEAM

Steam Notes

Steam is the term usually applied to the vapor-phase of water when this phase is reached by boiling the water. The term vapor describes the gaseous state of any substance, below its critical condition, from which it can be reduced to a liquid by compression. But water vapor is usually thought of only in a mixture with air, while the word steam has a much broader meaning. In a certain range of (low) pressures, the terms steam and water vapor are used interchangeably.

"Boiling point" is the temperature at which a liquid boils—that is, changes rapidly and violently into vapor, (or steam, if the liquid is water), through the application of heat. When the pressure exerted upon the liquid is 760 mm Hg or 14.696 lb per sq in abs., the boiling point of water is 212°F or 100°C. The temperature at which water boils varies, however, with the pressure; water may actually boil at freezing temperature (32°F) provided the pressure is held down to .0885 lb per sq in; on the other hand its maximum boiling temperature (the critical temperature), is approximately 705°F, under a pressure of some 3200 lb per sq in.

Steam, or water vapor, is invisible. Only through partial condensation does it appear as a mist. Steam may exist either in saturated form, while in contact with water, or as superheated steam, after separation from the water from which it was generated and further heating. Saturated steam may be dry or wet; in the latter case it carries free moisture and the amount of moisture determines the "quality" of the steam. The exhaust from a steam turbine or engine is usually wet steam. The temperature of dry-or wet saturated steam at a given pressure is the same and is determined entirely by the absolute pressure. If the pressure is maintained, the temperature will remain constant as condensation proceeds. Removal of heat produces condensation.

Superheated steam behaves like a gas; when compressed, its pressure rises; when heated at constant pressure its volume increases, when heated at constant volume its pressure rises, etc. Its condition is usually indicated by the "degrees of superheat" above the saturation temperature, and by its pressure.

1 cu ft of water, evaporated at 212°F and 14.696 lb per sq in absolute pressure, becomes 1606 cu ft of dry-saturated steam.

1 cu ft of steam weighs .03731 lb, and 1 lb of steam occupies 26.80 cu ft, at a pressure of 14.696 lb per sq in and a temperature of 212°F.

1 cu ft of dry air weighs .08073 lb, and 1 lb of dry air occupies 12.387 cu ft at pressure of 14.696 lb per sq in and a temperature of 32°F.

The amount of heat required to transform a liquid into its vapor, the temperature remaining constant, is called the latent heat of vaporization. The value of the latent heat varies with the pressure under which the liquid is caused to vaporize.

The latent heat of vaporization of water to steam is 970.3 Btu per lb at atmospheric pressure.

The Btu (British thermal unit) is equivalent to 778.0 ft-lb, which is the heat energy required to raise the temperature of 1 lb of water 1°F in the range from 32 to 212°F. In the metric system use is made of the term calorie (cal) or gram-calorie which is the heat required to raise the temperature of 1 gram of water 1°C within the range from 0 to 100°C. The kilogram-calorie or large calorie is 1000 gram-calories.

The best designed boilers, well set, with good draft and skillful firing, will evaporate from 7 to 10 lb of water per lb of first class coal.

A boiler horsepower is equivalent to 34.5 lb of water evaporated per hr from and at 212°F, and is equivalent to 33,475 Btu per hr.

With small boilers in industrial plants, heat liberations of approximately 15,000 Btu per cu ft of furnace volume per hr are attained; whereas, in large central stations this can run up to 30,000 Btu per cu ft or higher.

Requirements in U.S. gpm for Boiler Feeding

Boiler hp	gpm	lb per hr	Boiler hp	gpm	lb per hr
50	4	1,725	2,500	172	86,250
75	5	2,587	3,000	207	103,500
100	7	3,450	3,500	242	120,750
150	10	5,175	4,000	276	138,000
175	12	6,037	4,500	310	155,250
200	14	6,900	5,000	345	172,500
225	16	7,762	10,000	689	345 000
250	17	8,625	15,000	1,034	517,500
275	19	9,487	20,000	1,387	690,000
300	21	10,350	25,000	1,723	862,500
350	24	12,075	35,000	2,413	1,207,500
400	28	13,800	40,000	2,759	1,380,000
500	34	17,250	45,000	3,102	1,550,000
750	53	25,875	50,000	3,447	1,725,000
1,000	69	34,500	60,000	4,136	2,070,000
1,500	104	51,750	80,000	5,515	2,760,000
2,000	138	69,000	100,000	6,894	3,450,000

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Note: (a) gpm is given to the nearest whole number.

(b) The above water quantities are based on 34.5 lb of water evaporated per hour from and at 212 deg F. The weight of one gallon of water is taken as being equal to 8.34 lb at 60 deg F. Intermediate water quantities in gal per min are obtainable by multiplying the boiler hp by .069.

(c) In selecting boiler feed pumps, the fact that boilers are often run two or three hundred per cent of rating should be taken into consideration. The above figures are of the actual boiler horsepower developed.

(d) Boiler feed pumps should have pressure in excess of the boiler rated pressure in order to compensate for frictional losses, entrance losses, regulating valve losses, and normal static head. These should be specified for a particular installation. However, for estimating purposes, the following are fair values:

Boiler Pressure	Boiler Feed Pump Discharge Pressure
200	250
400	475
800	925
1200	1350
1600	1920
2000	2400
2400	2880

Properties of Saturated Steam—Temperature Table
32° to 212° F

Temp °F	Absolute Pressure			Vacuum In Hg Ref to 29.921″ Bar at 32°F	Specific volume sat vap ft³/lb	Total Heat or Enthalpy Btu per lb		
	In Hg	mm Hg	Lb/ Sq In			Sat. Liquid	Evap	Sat Vapor
32	0.1803	4.579	0.08854	29.741	3306.	0.00	1075.8	1075.8
33	0.188	4.77	0.0922	29.733	3180.	1.01	1075.2	1076.2
34	0.196	4.97	0.0960	29.725	3061.	2.02	1074.7	1076.7
35	0.204	5.17	0.1000	29.717	2947.	3.02	1074.1	1077.1
36	0.212	5.38	0.1040	29.709	2837.	4.03	1073.6	1077.6
37	0.220	5.60	0.1082	29.701	2732.	5.04	1073.0	1078.0
38	0.229	5.82	0.1126	29.692	2632.	6.04	1072.4	1078.4
39	0.238	6 05	0.1171	29.683	2536.	7.04	1071.9	1078.9
40	0.248	6.29	0.1217	29.673	2444.	8.05	1071.3	1079.3
41	0.258	6.54	0.1265	29.663	2356.	9.05	1070.7	1079.7
42	0.268	6.80	0.1315	29.653	2271.	10.05	1070.1	1080.2
43	0.278	7.07	0.1367	29.643	2190.	11.06	1069.5	1080.6
44	0.289	7.34	0.1420	29.632	2112.	12.06	1068.9	1081.0
45	0.300	7.63	0.1475	29.621	2036.4	13.06	1068.4	1081.5
46	0.312	7.93	0.1532	29.609	1964.3	14.06	1067.8	1081.9
47	0.324	8.23	0.1591	29.597	1895.1	15.07	1067.3	1082.4
48	0.336	8.55	0.1653	29.585	1828.6	16.07	1066.7	1082.8
49	0.349	8.87	0.1716	29.572	1764.7	17.07	1066.1	1083.2
50	0.363	9.21	0.1781	29.558	1703.2	18.07	1065.6	1083.7
51	0.376	9.56	0.1849	29.545	1644.2	19.07	1065.0	1084.1
52	0.391	9.92	0.1918	29.530	1587.6	20.07	1064 4	1084.5
53	0.405	10.29	0.1990	29.516	1533.3	21.07	1063.9	1085.0
54	0.420	10.68	0.2064	29.501	1481.0	22.07	1063.3	1085.4
55	0.436	11.07	0.2141	29.485	1430.7	23.07	1062.7	1085.8
56	0.452	11.48	0.2220	29.469	1382.4	24.06	1062.2	1086.3
57	0.469	11.90	0.2302	29.452	1335.9	25.06	1061.6	1086.7
58	0.436	12.34	0.2386	29.435	1291.1	26.06	1061.0	1087.1
59	0.504	12.79	0.2473	29.417	1248.1	27.06	1060.5	1087.6
60	0 522	13.25	0.2563	29.399	1206.7	28.06	1059.9	1088.0
61	0 541	13.73	0.2655	29.380	1166.8	29.06	1059.3	1088.4
62	0.560	14.23	0.2751	29.361	1128.4	30 05	1058 8	1088.9
63	0.580	14.74	0.2850	29.341	1091.4	31.05	1058.2	1089.3
64	0.601	15.26	0.2951	29.320	1055.7	32.05	1057.6	1089.7
65	0.622	15.80	0.3056	29.299	1021.4	33.05	1057.1	1090.2
66	0.644	16.36	0.3164	29.277	988.4	34.05	1056.5	1090.6
67	0 667	16.94	0.3276	29.254	956.6	35.05	1056 0	1091.0
68	0.690	17.53	0 3390	29.231	925 9	36.04	1055.5	1091.5
69	0.714	18.15	0.3509	29.207	896.3	37.04	1054.9	1091.9
70	0.739	18.78	0.3631	29.182	867.9	38.04	1054.3	1092.3
71	0.765	19.43	0.3756	29.156	840.4	39.04	1053.8	1092.8
72	0.791	20.10	0 3886	29.130	813.9	40.04	1053.2	1093.2
73	0.818	20.79	0.4019	29.103	788.4	41.03	1052.6	1093.6
74	0.846	21.49	0.4156	29.075	763 8	42.03	1052.1	1094.1
75	0.875	22.23	0.4298	29.046	740.0	43.03	1051.5	1094.5
76	0.905	22.98	0.4443	29.016	717.1	44 03	1050.9	1094.9
77	0.935	23.75	0.4593	28.986	694.9	45 02	1050.4	1095.4
78	0.967	24.55	0.4747	28.954	673.6	46 02	1049.8	1095.8
79	0.999	25.37	0.4906	28.922	653.0	47.02	1049.2	1096.2
80	1.032	26.22	0.5069	28.889	633.1	48 02	1048.6	1096.6
81	1.066	27.09	0.5237	28.855	613.9	49.02	1048.1	1097.1
82	1.102	27.98	0.5410	28.819	595.3	50.01	1047.5	1097.5
83	1.138	28.90	0.5588	28.783	577.4	51.01	1046.9	1097.9
84	1.175	29.85	0.5771	28.746	560.2	52.01	1046.4	1098.4

Properties of Saturated Steam—Temperature Table 32° to 212° F (Continued)

Temp °F	Absolute Pressure			Vacuum In Hg Ref to 29.921″ Bar at 32°F	Specific Volume Sat Vap cu ft. Lb	Total Heat or Enthalpy Btu per lb		
	In Hg	mm Hg	Lb. Sq In			Sat Liquid	Evap	Sat Vapor
85	1.213	30.82	0.5959	28.708	543.5	53.00	1045.8	1098.8
86	1.253	31.82	0.6152	28.668	527.3	54.00	1045.2	1099.2
87	1.293	32.85	0.6351	28.628	511.7	55.00	1044.7	1099.7
88	1.335	33.90	0.6556	28.586	496.7	56.00	1044.1	1100.1
89	1.378	34.99	0.6766	28.543	482.1	56.99	1043.5	1100.5
90	1.422	36.11	0.6982	28.499	468.0	57.99	1042.9	1100.9
91	1.467	37.25	0.7204	28.454	454.4	58.99	1042.4	1101.4
92	1.513	38.43	0.7432	28.408	441.3	59.99	1041.8	1101.8
93	1.561	39.64	0.7666	28.360	428.5	60.98	1041.2	1102.2
94	1.610	40.89	0.7906	28.311	416.2	61.98	1040.7	1102.6
95	1.660	42.16	0.8153	28.261	404.3	62.98	1040.1	1103.1
96	1.712	43.48	0.8407	28.209	392.8	63.98	1039.5	1103.5
97	1.765	44.82	0.8668	28.156	381.7	64.97	1038.9	1103.9
98	1.819	46.21	0.8935	28.102	370.9	65.97	1038.4	1104.4
99	1.875	47.63	0.9210	28.046	360.5	66.97	1037.8	1104.8
100	1.933	49.09	0.9492	27.988	350.4	67.97	1037.2	1105.2
101	1.992	50.58	0.9781	27.929	340.6	68.96	1036.6	1105.6
102	2.052	52.12	1.0078	27.869	331.1	69.96	1036.1	1106.1
103	2.114	53.69	1.0382	27.807	321.9	60.96	1035.5	1106.5
104	2.178	55.31	1.0695	27.743	313.1	71.96	1034.9	1106.9
105	2.243	56.97	1.1016	27.678	304.5	72.95	1034.3	1107.3
106	2.310	58.67	1.1345	27.611	296.2	73.95	1033.8	1107.8
107	2.379	60.42	1.1683	27.542	288.1	74.95	1033.3	1108.2
108	2.449	62.21	1.2029	27.472	280.3	75.95	1032.7	1108.6
109	2.521	64.04	1.2384	27.400	272.7	76.94	1032.1	1109.1
110	2.596	65.93	1.2748	27.325	265.4	77.94	1031.6	1109.5
111	2.672	67.86	1.3121	27.249	258.3	78.94	1031.0	1109.9
112	2.749	69.84	1.3504	27.172	251.4	79.94	1030.4	1110.3
113	2.829	71.86	1.3896	27.092	244.7	80.94	1029.8	1110.7
114	2.911	73.94	1.4298	27.010	238.2	81.93	1029.2	1111.1
115	2.995	76.07	1.4709	26.926	231.9	82.93	1028.7	1111.6
116	3.081	78.25	1.5130	26.840	225.8	83.93	1028.1	1112.0
117	3.169	80.49	1.5563	26.752	219.9	84.93	1027.5	1112.4
118	3.259	82.78	1.6006	26.662	214.2	85.92	1026.9	1112.8
119	3.351	85.12	1.6459	26.570	208.7	86.92	1026.3	1113.2
120	3.466	87.52	1.6924	26.475	203.27	87.92	1025.8	1113.7
121	3.543	89.99	1.7400	26.378	198.03	88.92	1025.2	1114.1
122	3.642	92.51	1.7888	26.279	192.95	89.92	1024.6	1114.5
123	3.744	95.09	1.8387	26.177	188.02	90.91	1024.0	1114.9
124	3.848	97.73	1.8897	26.073	183.25	91.91	1023.4	1115.3
125	3.954	100.43	1.9420	25.967	178.61	92.91	1022.9	1115.8
126	4.063	103.20	1.9955	25.858	174.10	93.91	1022.3	1116.2
127	4.175	106.32	2.0503	25.746	169.72	94.91	1021.7	1116.6
128	4.289	108.94	2.1064	25.632	165.47	95.91	1021.1	1117.0
129	4.406	111.90	2.1638	25.515	161.35	96.90	1020.5	1117.4
130	4.525	114.94	2.2225	25.396	157.34	97.90	1020.0	1117.9
131	4.647	118.04	2.2826	25.274	153.44	98.90	1019.4	1118.3
132	4.773	121.22	2.3440	25.148	149.66	99.90	1018.8	1118.7
133	4.901	124.47	2.4069	25.020	145.99	100.90	1018.2	1119.1
134	5.031	127.80	2.4712	24.890	142.42	101.90	1017.6	1119.5
135	5.165	131.20	2.5370	24.756	138.95	102.90	1017.0	1119.9
136	5.302	134 68	2 6042	24 619	135 58	103 90	1016.4	1120.3
137	5.442	138.23	2.6729	24.479	132.30	104.89	1015.9	1120.8

Properties of Saturated Steam—Temperature Table 32° to 212° F (Continued)

Temp °F	Absolute Pressure In Hg	Absolute Pressure mm Hg	Absolute Pressure Lb/sq in	Vacuum In Hg Ref to 29.921" Bar at 32°F	Specific Volume Sat Vap cu ft/lb	Total Heat or Enthalpy Btu per lb Sat Liquid	Total Heat or Enthalpy Btu per lb Evap	Total Heat or Enthalpy Btu per lb Sat Vapor
138	5.585	141.86	2.743	24.336	129.12	105.89	1015.3	1121.2
139	5.732	145.58	2.815	24.189	126.02	106.89	1014.7	1121.6
140	5.881	149.38	2.889	24.040	123.01	107.89	1014.1	1122.0
141	6.034	153.27	2.964	23.887	120.08	108.89	1013.5	1122.4
142	6.190	157.23	3.040	23.731	117.23	109.89	1012.9	1122.8
143	6.350	161.29	3.119	23.571	114.46	110.89	1012.3	1123.2
144	6.513	165.44	3.199	23.408	111.77	111.89	1011.7	1123.6
145	6.680	169.67	3.281	23.24	109.15	112.89	1011.2	1124.1
146	6.850	173.99	3.365	23.07	106.60	113.89	1010.6	1124.5
147	7.024	178.41	3.450	22.90	104.12	114.89	1010.0	1124.9
148	7.202	182.93	3.537	22.72	101.71	115.89	1009.4	1125.3
149	7.384	187.55	3.627	22.53	99.36	116.89	1008.8	1125.7
150	7.569	192.25	3.718	22.35	97.07	117.89	1008.2	1126.1
151	7.759	197.08	3.811	22.16	94.85	118.89	1007.6	1126.5
152	7.952	201.98	3.906	21.97	92.68	119.89	1007.0	1126.9
153	8.150	207.01	4.003	21.77	90.57	120.89	1006.4	1127.3
154	8.351	212.12	4.102	21.57	88.52	121.89	1005.8	1127.7
155	8.557	217.35	4.203	21.36	86.52	122.89	1005.2	1128.1
156	8.767	222.68	4.306	21.15	84.58	123.89	1004.7	1128.6
157	8.981	228.12	4.411	20.94	82.69	124.89	1004.1	1129.0
158	9.200	233.68	4.519	20.72	80.84	125.89	1003.5	1129.4
159	9.424	239.37	4.629	20.50	79.04	126.89	1002.9	1129.8
160	9.652	245.16	4.741	20.27	77.29	127.89	1002.3	1130.2
161	9.885	251.08	4.855	20.03	75.58	128.89	1001.7	1130.6
162	10.122	257.10	4.971	19.80	73.92	129.89	1001.1	1131.0
163	10.364	263.25	5.090	19.55	72.30	130.89	1000.5	1131.4
164	10.611	269.52	5.212	19.31	70.73	131.89	999.9	1131.8
165	10.863	275.92	5.335	19.06	69.19	132.89	999.3	1132.2
166	11.120	282.45	5.461	18.80	67.69	133.89	998.7	1132.6
167	11.382	289.10	5.590	18.54	66.23	134.89	998.1	1133.0
168	11.649	295.89	5.721	18.27	64.80	135.90	997.5	1133.4
169	11.921	302.79	5.855	18.00	63.41	136.90	996.9	1133.8
170	12.199	309.86	5.992	17.72	62.06	137.90	996.3	1134.2
171	12.483	317.07	6.131	17.44	60.74	138.90	995.7	1134.6
172	12.772	324.41	6.273	17.15	59.45	139.90	995.1	1135.0
173	13.066	331.88	6.417	16.86	58.20	140.90	994.5	1135.4
174	13.366	339.50	6.565	16.56	56.97	141.90	993.9	1135.8
175	13.671	347.24	6.715	16.25	55.78	142.91	993.3	1136.2
176	13.983	355.17	6.868	15.94	54.61	143.91	992.7	1136.6
177	14.301	363.25	7.024	15.62	53.48	144.91	992.1	1137.0
178	14.625	371.48	7.183	15.30	52.37	145.91	991.5	1137.4
179	14.955	379.86	7.345	14.97	51.29	146.92	990.8	1137.7
180	15.291	388.39	7.510	14.63	50.23	147.92	990.2	1138.1
181	15.633	397.08	7.678	14.29	49.20	148.92	989.6	1138.5
182	15.982	405.94	7.850	13.94	48.19	149.92	989.0	1138.9
183	16.337	414.96	8.024	13.58	47.21	150.93	988.4	1139.3
184	16.699	424.16	8.202	13.22	46.25	151.93	987.8	1139.7
185	17.068	433.53	8.383	12.85	45.31	152.93	987.2	1140.1
186	17.443	443.05	8.567	12.48	44.40	153.94	986.6	1140.5
187	17.825	452.76	8.755	12.10	43.51	154.94	986.0	1140.9
188	18.214	462.64	8.946	11.71	42.64	155.94	985.4	1141.3
189	18.611	472.72	9.141	11.31	41.79	156.95	984.8	1141.7
190	19.014	482.96	9.339	10.91	40.96	157.95	984.1	1142.0

Properties of Saturated Steam—Temperature Table 32° to 212° F (Continued)

Temp °F	Absolute Pressure			Vacuum In Hg Ref to 29.921" Bar at 32°F	Specific Volume Sat Vap cu ft/lb	Total Heat or Enthalpy Btu per lb		
	In Hg	mm Hg	lb/sq in			Sat Liquid	Evap	Sat Vapor
191	19.425	493.40	9.541	10.50	40.15	158.95	983.4	1142.4
192	19.843	504 01	9.746	10.08	39.36	159 96	982.8	1142.8
193	20.269	514.83	9.955	9.65	38.58	160.96	982.2	1143.2
194	20.703	525.86	10.168	9.22	37.83	161.97	981.6	1143.6
195	21 144	537.06	10.385	8.78	37.09	162.97	981.0	1144.0
196	21.593	548.46	10.605	8.33	36.37	163.97	980.4	1144.4
197	22.050	560.07	10.830	7.87	35.66	164.98	979.7	1144.7
198	22.515	571.88	11.058	7.41	34.97	165.98	979.1	1145.1
199	22.987	583.87	11.290	6.93	34.30	166.99	978.5	1145.5
200	23.467	596.06	11.526	6.45	33.64	167.99	977.9	1145.9
201	23.957	608.51	11.767	5.96	32.99	169.00	977.2	1146.3
202	24.455	621.16	12.011	5.47	32.37	170.00	976.6	1146.6
203	24.960	633.98	12.259	4.96	31.75	171.01	976.0	1147.0
204	25.475	647.07	12.512	4.44	31.15	172.02	975.4	1147.4
205	25.998	660.35	12.769	3.92	30.56	173.02	974.8	1147.8
206	26.531	673.89	13 031	3.39	29 99	174.03	974.2	1148.2
207	27 074	687.68	13.297	2.85	29.43	175.03	973.5	1148 5
208	27.625	701.68	13.568	2.30	28.88	176.04	972.9	1148.9
209	28.185	715.90	13.844	1.74	28.34	177.04	972.2	1149.3
210	28.755	730.38	14.123	1.16	27.82	178.05	971.6	1149.7
211	29.334	745.08	14.406	0.59	27.31	179.06	970.9	1150.0
212	29.921	760.00	14.696	0.00	26.80	180.07	970.3	1150.4

Tables on pages 140 to 143 reproduced by permission of the authors and publishers from "Thermodynamic Properties of Steam" by Keenan and Keyes (1936) except absolute pressures in mm Hg and lb per sq in and vacuum in in. Hg which were calculated by Ingersoll-Rand.

Any pressure may be expressed in a number of different units by using the following conversion formulae:

standard atmosphere = 14.696 lb/sq in
1 standard atmosphere = 29.9213 inches Hg (at 32° F)
1 standard atmosphere = 34.00 ft water (at 75° F)
1 standard atmosphere = 76 cm or 760 mm Hg (at O° C)
1 pound per square inch = 2.036 inches Hg (at 32° F)
1 pound per square inch = 27.763 inches water (at 75° F)
1 inch Hg (at 32° F) = .491 pounds per square inch.
1 inch Hg = 25.4 millimeters Hg
1 kg cm² = 14.223 lb/sq in

Properties of Saturated Steam—Pressure: In Hg Abs

Absolute Pressure in Hg	Temp °F	Sp Vol cu ft /lb
.05	5.43	11200.
.06	9.03	9400.
.07	12.11	8300.
.08	14.83	7250.
.09	17.24	6500.
.10	19.44	5860.
.11	21.42	5320.
.12	23.25	4960.
.13	24.94	4520.
.14	26.53	4210.
.15	28.00	3950.
.16	29.39	3730.
.17	30.72	3500.
.18	31.96	3310.
.1803	32.00	3306.
.19	33.28	3147.
.20	34.56	2997.
.21	35.78	2861.
.22	36.96	2736.
.23	38.09	2624.
.24	39.18	2520.
.25	40.23	2424.
.26	41.23	2336.
.27	42.22	2253.
.28	43.17	2177.
.29	44.08	2106.
.30	44.96	2039.
.31	45.83	1976.8
.32	46.67	1917.9
.33	47.48	1863.0
.34	48.28	1810.9
.35	49.05	1761.6
.36	49.80	1715.3
.37	50.53	1671.1
.38	51.25	1629.9
.39	51.96	1590.0
.40	52.64	1553.0
.41	53.31	1517.0
.42	53.98	1482.0
.43	54.62	1449.9
.44	55.25	1418.5
.45	55.88	1388.4
.46	56.48	1360.0
.47	57.08	1332.3
.48	57.66	1306.2
.49	58.24	1280.9

Absolute Pressure in Hg	Temp °F	Sp Vol cu ft /lb
.50	58.80	1256.5
.51	59.35	1233.6
.52	59.90	1210.9
.53	60.43	1189.5
.54	60.96	1168.3
.55	61.48	1148.4
.56	62.00	1128.6
.57	62.49	1110.2
.58	62.99	1091.9
.59	63.47	1074.6
.60	63.96	1057.3
.61	64.43	1041.0
.62	64.90	1024.9
.63	65.35	1009.7
.64	65.81	994.7
.65	66.26	980.3
.66	66.70	966.3
.67	67.13	952.5
.68	67.56	939.4
.69	67.99	926.3
.70	68.40	914.0
.71	68.82	901.7
.72	69.23	889.9
.73	69.63	878.4
.74	70.03	867.1
.75	70.43	856.1
.76	70.81	845.5
.77	71.20	835.1
.78	71.58	825.0
.79	71.96	815.1
.80	72.33	805.6
.81	72.70	796.2
.82	73.06	786.9
.83	73.42	778.0
.84	73.78	769.2
.85	74.13	760.7
.86	74.48	752.4
.87	74.83	744.1
.88	75.17	736.2
.89	75.51	728.4
.90	75.85	720.7
.91	76.18	713.2
.92	76.51	705.9
.93	76.83	698.7
.94	77.15	691.7
.95	77.47	684.8
.96	77.79	678.1
.97	78.11	671.4
.98	78.42	665.0
.99	78.73	658.7

Absolute Pressure in Hg	Temp °F	Sp Vol cu ft/lb
1.00	79.03	652.3
1.01	79.33	646.4
1.02	79.64	640.4
1.03	79.94	634.4
1.04	80.23	628.7
1.05	80.52	623.1
1.06	80.81	617.5
1.07	81.10	612.0
1.08	81.39	606.7
1.09	81.67	601.4
1.10	81.95	596.2
1.11	82.23	591.2
1.12	82.51	586.2
1.13	82.78	581.3
1.14	83.06	576.5
1.15	83.33	571.8
1.16	83.60	567.1
1.17	83.87	562.5
1.18	84.13	558.1
1.19	84.39	553.7
1.20	84.65	549.3
1.21	84.91	544.9
1.22	85.17	540.7
1.23	85.43	536.6
1.24	85.68	532.5
1.25	85.93	528.4
1.26	86.18	524.5
1.27	86.43	520.6
1.28	86.68	516.7
1.29	86.92	512.9
1.30	87.17	509.2
1.31	87.41	505.6
1.32	87.65	502.0
1.33	87.89	498.4
1.34	88.12	494.9
1.35	88.36	491.5
1.36	88.59	488.1
1.37	88.83	484.7
1.38	89.06	481.3
1.39	89.28	478.1
1.40	89.51	474.9
1.41	89.74	471.7
1.42	89.97	468.5
1.43	90.19	465.4
1.44	90.41	462.4
1.45	90.63	459.4
1.46	90.85	456.4
1.47	91.07	453.5
1.48	91.29	450.6
1.49	91.50	447.8

Sp vol for temp below 32°F are approximate.

Properties of Saturated Steam—Pressure; In Hg Abs (Continued)

Absolute Pressure in Hg	Temp °F	Sp Vol cu ft /lb	Absolute Pressure in Hg	Temp °F	Sp. Vol cu ft/lb	Absolute Pressure in Hg	Temp °F	Sp Vol cu ft/lb
1.50	91.72	445.0	2.00	101.14	339.3	2.50	108.71	274.9
1.51	91.93	442.2	2.01	101.31	337.7	2.51	108.84	273.9
1.52	92.14	439.5	2.02	101.47	336.1	2.52	108.98	272.9
1.53	92.35	436.8	2.03	101.64	334.5	2.53	109.12	271.9
1.54	92.56	434.1	2.04	101.80	333.0	2.54	109.25	270.9
1.55	92.77	431.4	2.05	101.97	331.4	2.55	109.39	269.9
1.56	92.98	428.7	2.06	102.13	329.9	2.56	109.52	268.9
1.57	93.19	426.2	2.07	102.30	328.4	2.57	109.66	267.9
1.58	93.39	423.7	2.08	102.46	326.9	2.58	109.79	266.9
1.59	93.60	421.2	2.09	102.62	325.4	2.59	109.92	266.0
1.60	93.80	418.7	2.10	102.78	324.0	2.60	110.06	265.0
1.61	94.00	416.2	2.11	102.94	322.5	2.61	110.19	264.0
1.62	94.20	413.8	2.12	103.10	321.1	2.62	110.32	263.1
1.63	94.40	411.4	2.13	103.25	319.7	2.63	110.46	262.2
1.64	94.60	409.0	2.14	103.41	318.3	2.64	110.59	261.2
1.65	94.80	406.6	2.15	103.57	316.9	2.65	110.72	260.3
1.66	95.01	404.3	2.16	103.73	315.5	2.66	110.85	259.4
1.67	95.20	402.0	2.17	103.88	314.1	2.67	110.98	258.4
1.68	95.39	399.8	2.18	104.04	312.8	2.68	111.11	257.5
1.69	95.59	397.6	2.19	104.19	311.5	2.69	111.24	256.6
1.70	95.78	395.4	2.20	104.34	310.2	2.70	111.37	255.8
1.71	95.97	393.2	2.21	104.50	308.8	2.71	111.49	254.9
1.72	96.16	391.1	2.22	104.65	307.5	2.72	111.62	254.0
1.73	96.35	389.0	2.23	104.80	306.2	2.73	111.75	253.1
1.74	96.54	386.9	2.24	104.95	304.9	2.74	111.88	252.2
1.75	96.72	384.8	2.25	105.11	303.6	2.75	112.01	251.4
1.76	96.91	382.7	2.26	105.26	302.4	2.76	112.13	250.5
1.77	97.10	380.7	2.27	105.41	301.1	2.77	112.26	249.7
1.78	97.28	378.7	2.28	105.55	299.9	2.78	112.38	248.8
1.79	97.46	376.7	2.29	105.70	298.7	2.79	112.51	248.0
1.80	97.65	374.7	2.30	105.85	297.4	2.80	112.63	247.2
1.81	97.83	372.7	2.31	106.00	296.2	2.81	112.76	246.3
1.82	98.01	370.8	2.32	106.15	295.0	2.82	112.88	245.5
1.83	98.19	368.9	2.33	106.29	293.8	2.83	113.01	244.7
1.84	98.37	367.0	2.34	106.44	292.7	2.84	113.13	243.9
1.85	98.55	365.2	2.35	106.58	291.5	2.85	113.25	243.1
1.86	98.73	363.3	2.36	106.73	290.3	2.86	113.37	242.3
1.87	98.91	361.4	2.37	106.87	289.1	2.87	113.50	241.5
1.88	99.09	359.6	2.38	107.02	287.9	2.88	113.62	240.7
1.89	99.26	357.9	2.39	107.16	286.8	2.89	113.74	239.9
1.90	99.44	356.1	2.40	107.31	285.7	2.90	113.86	239.1
1.91	99.61	354.4	2.41	107.45	284.6	2.91	113.98	238.3
1.92	99.78	352.6	2.42	107.59	283.5	2.92	114.11	237.5
1.93	99.96	350.8	2.43	107.73	282.4	2.93	114.23	236.8
1.94	100.13	349.1	2.44	107.87	281.3	2.94	114.35	236.0
1.95	100.30	347.5	2.45	108.01	280.2	2.95	114.46	235.3
1.96	100.47	345.8	2.46	108.15	279.2	2.96	114.58	234.5
1.97	100.64	344.1	2.47	108.29	278.1	2.97	114.70	233.8
1.98	100.81	342.5	2.48	108.43	277.0	2.98	114.82	233.0
1.99	100.97	340.9	2.49	108.57	276.0	2.99	114.94	232.2

Properties of Saturated Steam—Pressure; In. Hg Abs (Continued)

Absolute Pressure in Hg	Temp °F	Sp Vol cu ft/lb	Absolute Pressure in Hg	Temp °F	Sp Vol cu ft/lb	Absolute Pressure in Hg	Temp °F	Sp Vol cu ft/lb
3.00	115.06	231.5	4.20	127.22	168.8	12.00	169.3	63.0
3.05	115.64	228.0	4.30	128.10	165.1	12.50	171.1	60.7
3.10	116.22	224.5	4.40	128.95	161.5	13.00	172.8	58.5
3.15	116.79	221.2	4.50	129.79	158.2	13.50	174.4	56.5
3.20	117.35	217.9	4.60	130.61	155.0	14.00	176.1	54.6
3.25	117.90	214.8	4.70	131.42	151.8	14.50	177.6	52.8
3.30	118.45	211.8	4.80	132.22	148.9	15.00	179.1	51.1
3.35	118.99	208.8	4.90	133.00	146.0	16.00	182.1	48.1
3.40	119.52	205.9	5.00	133.8	143.3	17.00	184.8	45.5
3.45	120.04	203.0	5.50	137.4	131.0	18.00	187.5	43.1
3.50	120.56	200.3	6.00	140.8	120.7	19.00	190.0	41.0
3.55	121.07	197.7	6.50	143.9	112.0	20.00	192.4	39.1
3.60	121.58	195.1	7.00	146.9	104.5	21.00	194.7	37.3
3.65	122.08	192.6	7.50	149.6	97.9	22.00	196.9	35.7
3.70	122.57	190.1	8.00	152.2	92.2	23.00	199.0	34.3
3.75	123.06	187.7	8.50	154.7	87.0	24.00	201.1	32.9
3.80	123.55	185.4	9.00	157.1	82.5	25.00	203.1	31.7
3.85	124.02	183.2	9.50	159.3	78.4	26.00	205.0	30.6
3.90	124.49	181.0	10.00	161.5	74.8	27.00	206.9	29.5
3.95	124.97	178.8	10.50	163.6	71.4	28.00	208.7	28.5
4.00	125.42	176.7	11.00	165.5	68.4	29.00	210.4	27.6
4.10	126.33	172.6	11.50	167.4	65.6	29.92	212.0	26.8

Values from .05 to .18 in Hg reproduced by permission from Chemical Engineers Handbook by John H. Perry, published by McGraw-Hill Book Co., Inc.

Values from .1803 to 29.92 in Hg calculated graphically by Ingersoll-Rand Co. by permission of the authors and publisher from data in "Thermodynamic Properties of Steam" by Keenan and Keyes. (1936).

For correction of observed vacuum and barometer to standard condition see pages 203 to 206.

Properties of Saturated Steam—Pressure: mm Hg Abs

Absolute Pressure mm Hg	Temp °F	Sp Vol cu ft/lb	Absolute Pressure mm Hg	Temp °F	Sp Vol cu ft /lb	Absolute Pressure mm Hg	Temp °F	Sp Vol cu ft /lb
1.5	8.73	9700.	25.0	78.55	662.3	50.0	100.61	344.4
2.0	14.50	7300.	25.5	79.15	650.0	50.5	100.94	341.2
2.5	19.09	5920.	26.0	79.74	638.2	51.0	101.27	338.0
3.0	22.91	4950.	26.5	80.33	626.8	51.5	101.60	334.9
3.5	26.19	4250.	27.0	80.90	615.8	52.0	101.92	331.9
4.0	29.05	3780.	27.5	81.46	605.3	52.5	102.24	328.9
4.5	31.62	3380.	28.0	82.02	594.9	53.0	102.56	326.0
			28.5	82.56	585.2	53.5	102.88	323.1
			29.0	83.10	575.6	54.0	103.19	320.2
			29.5	83.63	566.5	54.5	103.50	317.5
4.579	32.00	3306.	30.0	84.16	557.5	55.0	103.81	314.8
5.0	34.17	3042.	30.5	84.67	549.0	55.5	104.12	312.1
5.5	36.55	2779.	31.0	85.19	540.5	56.0	104.41	309.5
6.0	38.77	2558.	31.5	85.68	532.4	56.5	104.72	306.9
6.5	40.82	2372.	32.0	86.18	524.6	57.0	105.02	304.4
7.0	42.75	2211.	32.5	86.66	516.9	57.5	105.31	301.9
7.5	44.55	2070.4	33.0	87.15	509.5	58.0	105.61	299.5
8.0	46.25	1946.8	33.5	87.62	502.4	58.5	105.90	297.1
8.5	47.86	1838.0	34.0	88.09	495.4	59.0	106.19	294.7
9.0	49.37	1741.8	34.5	88.55	488.6	59.5	106.47	292.4
9.5	50.83	1654.4						
10.0	52.21	1576.1	35.0	89.01	482.0	60.0	106.76	290.1
10.5	53.55	1504.7	35.5	89.46	475.6	60.5	107.05	287.8
11.0	54.82	1439.8	36.0	89.91	469.3	61.0	107.33	285.6
11.5	56.05	1380.1	36.5	90.34	463.3	61.5	107.61	283.4
12.0	57.22	1326.0	37.0	90.78	457.4	62.0	107.88	281.2
12.5	58.36	1275.8	37.5	91.21	451.7	62.5	108.16	279.1
13.0	59.45	1229.5	38.0	91.63	446.1	63.0	108.43	277.0
13.5	60.51	1186.2	38.5	92.05	440.6	63.5	108.71	274.9
14.0	61.54	1146.1	39.0	92.47	435.3	64.0	108.98	272.9
14.5	62.54	1108.6	39.5	92.88	430.0	64.5	109.24	270.9
15.0	63.50	1073.6	40.0	93.29	425.0	65.0	109.51	269.0
15.5	64.44	1040.7	40.5	93.69	420.0	65.5	109.77	267.1
16.0	65.35	1009.8	41.0	94.09	415.1	66.0	110.04	265.2
16.5	66.24	980.8	41.5	94.48	410.4	66.5	110.30	263.3
17.0	67.10	953.5	42.0	94.87	405.8	67.0	110.56	261.4
17.5	67.94	927.7	42.5	95.26	401.4	67.5	110.82	259.6
18.0	68.76	903.3	43.0	95.64	397.0	68.0	111.07	257.8
18.5	69.56	880.4	43.5	96.11	392.7	68.5	111.33	256.0
19.0	70.34	858.5	44.0	96.39	388.4	69.0	111.58	254.3
19.5	71.11	837.5	44.5	96.76	384.2	69.5	111.83	252.6
20.0	71.85	817.8	45.0	97.13	380.3	70.0	112.08	250.9
20.5	72.59	798.9	45.5	97.49	376.4	70.5	112.33	249.2
21.0	73.31	780.9	46.0	97.85	372.6	71.0	112.58	247.5
21.5	74.01	763.6	46.5	98.21	368.8	71.5	112.82	245.9
22.0	74.69	747.3	47.0	98.56	365.1	72.0	113.06	244.3
22.5	75.36	731.7	47.5	98.91	361.4	72.5	113.31	242.7
23.0	76.03	716.4	48.0	99.26	357.9	73.0	113.55	241.1
23.5	76.67	702.1	48.5	99.60	354.4	73.5	113.79	239.6
24.0	77.31	688.3	49.0	99.94	351.0	74.0	114.03	238.1
24.5	77.94	674.9	49.5	100.28	347.7	74.5	114.26	236.6

Sp vol for temp below 32°F are approximate.

Properties of Saturated Steam—Pressure; mm Hg Abs

Absolute Pressure mm Hg	Temp °F	Sp Vol cu ft/lb	Absolute Pressure mm Hg	Temp °F	Sp Vol cu ft/lb	Absolute Pressure mm Hg	Temp °F	Sp Vol cu ft/lb
75.0	114.50	235.1	101.0	125.21	177.7	135.0	136.1	135.3
76.0	114.97	232.1	102.0	125.57	176.0	140.0	137.5	130.7
77.0	115.43	229.3	103.0	125.93	174.4	145.0	138.8	126.5
78.0	115.89	226.5	104.0	126.28	172.8	150.0	140.2	122.6
79.0	116.34	223.8	105.0	126.64	171.3	175.0	146.2	106.1
80.0	116.78	221.2	106.0	126.99	169.8	200.0	151.6	93.6
81.0	117.23	218.6	107.0	127.33	168.3	225.0	156.4	83.8
82.0	117.66	216.1	108.0	127.68	166.8	250.0	160.8	75.9
83.0	118.10	213.7	109.0	128.02	165.4	275.0	164.9	69.4
84.0	118.52	211.3	110.0	128.36	164.0	300.0	168.6	64.0
85.0	118.95	209.0	111.0	128.70	162.6	325.0	172.1	59.4
86.0	119.36	206.7	112.0	129.03	161.2	350.0	175.3	55.4
87.0	119.78	204.4	113.0	129.36	159.9	375.0	178.4	51.9
88.0	120.20	202.2	114.0	129.69	158.6	400.0	181.5	48.7
89.0	120.60	200.1	115.0	130.02	157.3	450.0	186.7	43.8
90.0	121.01	198.0	116.0	130.34	156.0	500.0	191.6	39.7
91.0	121.40	196.0	117.0	130.66	154.7	550.0	196.1	36.3
92.0	121.80	194.0	118.0	130.99	153.5	600.0	200.3	33.4
93.0	122.19	192.0	119.0	131.30	152.3	650.0	204.2	30.9
94.0	122.58	190.0	120.0	131.62	151.1	700.0	207.9	28.9
95.0	122.97	188.2	121.0	131.93	149.9	760.0	212.0	26.8
96.0	123.35	186.4	122.0	132.24	148.8			
97.0	123.73	184.6	123.0	132.55	147.7			
98.0	124.10	182.8	124.0	132.85	146.5			
99.0	124.47	181.1	125.0	133.16	145.4			
100.0	124.84	179.4	130.0	134.7	140.2			

Values from 1.5 to 4.5 mm Hg calculated from data in Chemical Engineers Handbook by John H. Perry, published by McGraw-Hill Book Co., Inc.

Values from 4.578 to 760 mm Hg calculated graphically by Ingersoll-Rand Co. by permission of the authors and publisher from data in "Thermodynamic Properties of Steam" by Keenan and Keyes, (1936).

Properties of Saturated Steam—Pressure Table

Abs press lb/in²	Temp °F	Specific Volume cu ft per lb		Total Heat Btu per lb		Entropy Btu/°F/lb		Abs press lb/in²
		Sat Liquid	Sat Vapor	Sat Liquid	Sat Vapor	Sat Liquid	Sat Vapor	
14.696	212.00	.01672	26.80	180.07	1150.4	.3120	1.7566	14.696
15	213.03	.01672	26.29	181.11	1150.8	.3135	1.7549	15
20	227.96	.01683	20.089	196.16	1156.3	.3356	1.7319	20
25	240.07	.01692	16 303	208.42	1160.6	.3533	1.7139	25
30	250.33	.01701	13.746	218.82	1164.1	.3680	1.6993	30
35	259.28	.01708	11.898	227.91	1167.1	.3807	1.6870	35
40	267.25	.01715	10.498	236 03	1169.7	.3919	1.6763	40
45	274.44	.01721	9.401	243.36	1172.0	.4019	1.6669	45
50	281 01	.01727	8.515	250.09	1174.1	.4110	1.6585	50
55	287.07	.01732	7.787	256.30	1175.9	.4193	1.6509	55
60	292.71	.01738	7.175	262.09	1177.6	.4270	1.6438	60
65	297.97	.01743	6.655	267.50	1179.1	.4342	1.6374	65
70	302.92	.01748	6.206	272.61	1180.6	.4409	1.6315	70
75	307.60	.01753	5.816	277.43	1181.9	.4472	1.6259	75
80	312.03	.01757	5.472	282 02	1183.1	.4531	1.6207	80
85	316.25	.01761	5.168	286.39	1184.2	.4587	1.6158	85
90	320.27	.01766	4.896	290 56	1185.3	.4641	1.6112	90
95	324.12	.01770	4.652	294 56	1186.2	.4692	1.6068	95
100	327.81	.01774	4.432	298 40	1187.2	.4740	1.6026	100
105	331.36	.01778	4.232	302.10	1188.1	.4787	1.5986	105
110	334.77	.01782	4.049	305.66	1188.9	.4832	1.5948	110
115	338.07	.01785	3.882	309.11	1189.7	.4875	1.5912	115
120	341.25	.01789	3 728	312 44	1190.4	.4916	1.5878	120
125	344.33	.01792	3.587	315 68	1191.1	.4956	1.5844	125
130	347.32	.01796	3.455	318.81	1191.7	.4995	1.5812	130
135	350.21	.01800	3.333	321.85	1192.4	.5032	1.5781	135
140	353.02	.01802	3 220	324.82	1193 0	.5069	1.5751	140
145	355 76	.01806	3.114	327.70	1193 5	.5104	1.5722	145
150	358.42	.01809	3.015	330 51	1194.1	.5138	1.5694	150
155	361.01	.01812	2.922	333.24	1194.6	.5172	1.5666	155
160	363.53	.01815	2.834	335.93	1195.1	.5204	1.5640	160
165	366.00	.01818	2.752	338.54	1195.6	.5235	1.5615	165
170	368.41	.01822	2.675	341.09	1196.0	.5266	1.5590	170
175	370.76	.01825	2.601	343.59	1196.5	.5296	1.5566	175
180	373.06	.01827	2.532	346.03	1196.9	.5325	1.5542	180
185	375.31	.01831	2.466	348 94	1197.3	.5354	1.5518	185
190	377.57	.01833	2.404	350.79	1197.6	.5381	1.5497	190
195	379.67	.01836	2.344	353.10	1198.0	.5409	1.5474	195
200	381.79	.01839	2.288	355.36	1198 4	.5435	1.5453	200
205	383.86	.01842	2.234	357.58	1198.7	.5461	1.5432	205
210	385.90	.01844	2.183	359.77	1199.0	.5487	1.5412	210
215	387.89	.01847	2.134	361.91	1199.3	.5512	1.5392	215
220	389.86	.01850	2.087	364.02	1199.6	.5537	1.5372	220
225	391.79	.01852	2.042	366.09	1199.9	.5561	1.5353	225
230	393.68	.01854	1.999	368.13	1200.1	.5585	1.5334	230

Properties of Saturated Steam—Pressure Table (Continued)

Abs press lb/in²	Temp °F	Specific Volume cu ft per lb		Total Heat Btu per lb		Entropy Btu/°F/lb		Abs press lb/in²
		Sat Liquid	Sat Vapor	Sat Liquid	Sat Vapor	Sat Liquid	Sat Vapor	
235	395.64	.01857	1.9579	370.14	1200.4	.5608	1.5316	235
240	397.37	.01860	1.9183	372.12	1200.6	.5631	1.5298	240
245	399.18	.01863	1.8803	374.08	1200.9	.5653	1.5280	245
250	400.95	.01865	1.8438	376.00	1201.1	.5675	1.5263	250
260	404.42	.01870	1.7748	379.76	1201.5	.5719	1.5229	260
270	407.78	.01875	1.7107	383.42	1201.9	.5760	1.5196	270
280	411.05	.01880	1.6511	386.98	1202.3	.5801	1.5164	280
290	414.23	.01885	1.5954	390.46	1202.6	.5841	1.5133	290
300	417.33	.01890	1.5433	393.84	1202.8	.5879	1.5104	300
320	423.29	.01899	1.4485	400.39	1203.4	.5952	1.5046	320
340	428.97	.01908	1.3645	406.66	1203.7	.6022	1.4992	340
360	434.40	.01917	1.2895	412.67	1204.1	.6090	1.4941	360
380	439.60	.01925	1.2222	418.45	1204.3	.6153	1.4891	380
400	444.59	.0193	1.1613	424.0	1204.5	.6214	1.4844	400
420	449.39	.0194	1.1061	429.4	1204.6	.6272	1.4799	420
440	454.02	.0195	1.0556	434.6	1204.6	.6329	1.4755	440
460	458.50	.0196	1.0094	439.7	1204.6	.6383	1.4713	460
480	462.82	.0197	.9670	444.6	1204.5	.6436	1.4673	480
500	467.01	.0197	.9278	449.4	1204.4	.6487	1.4634	500
550	476.93	.0199	.8422	460.8	1203.9	.6608	1.4542	550
600	486.21	.0201	.7698	471.6	1203.2	.6720	1.4454	600
650	494.89	.0203	.7084	481.8	1202.3	.6826	1.4373	650
700	503.10	.0205	.6554	491.5	1201.2	.6925	1.4296	700
750	510.85	.0207	.6093	500.8	1199.1	.7019	1.4223	750
800	518.23	.0209	.5687	509.7	1198.6	.7108	1.4153	800
850	525.26	.0210	.5328	518.3	1197.1	.7194	1.4085	850
900	531.98	.0212	.5006	526.6	1195.4	.7275	1.4020	900
950	538.42	.0214	.4717	534.6	1193.6	.7355	1.3957	950
1000	544.61	.0216	.4456	542.4	1191.8	.7430	1.3897	1000
1050	550.57	.0218	.4218	550.0	1189.9	.7504	1.3838	1050
1100	556.31	.0220	.4001	557.4	1187.8	.7575	1.3780	1100
1150	561.86	.0221	.3802	564.6	1185.6	.7644	1.3723	1150
1200	567.22	.0223	.3619	571.7	1183.4	.7711	1.3667	1200
1250	572.42	.0225	.3450	578.6	1181.0	.7776	1.3612	1250
1300	577.46	.0227	.3293	585.4	1178.6	.7840	1.3559	1300
1400	587.10	.0231	.3012	598.7	1173.4	.7963	1.3454	1400
1500	596.23	.0235	.2765	611.6	1167.9	.8082	1.3351	1500
1600	604.90	.0239	.2548	624.1	1162.1	.8196	1.3249	1600
1700	613.15	.0243	.2354	636.3	1155.9	.8306	1.3149	1700
1800	621.03	.0247	.2179	648.3	1149.4	.8412	1.3049	1800
2000	635.82	.0257	.1878	671.7	1135.1	.8619	1.2849	2000
2500	668.13	.0287	.1307	730.6	1091.1	.9126	1.2322	2500
3000	695.36	.0346	.0858	802.5	1020.3	.9731	1.1615	3000
3206.2	705.40	.0503	.0503	902.7	902.7	1.0580	1.0580	3206.2

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Properties of Superheated Steam

Abs Press Lb/In² (Sat temp)		* Sat Water	Sat Vapor	300°	400°	500°	600°	700°	800°	900°
1	v	.02	333.6	452.3	512.0	571.6	631.2	690.8	750.4	809.9
	h	69.7	1106.0	1195.8	1241.7	1288.3	1335.7	1383.8	1432.8	1482.7
(101.74)	s	.1362	1.9782	2.1153	2.1720	2.2233	2.2702	2.3137	2.3542	2.3923
5	v	.02	73.52	90.25	102.26	114.22	126.16	138.10	150.03	161.95
	h	130.1	1131.1	1195.0	1241.2	1288.0	1335.4	1383.6	1432.7	1482.6
(162.24)	s	.2347	1.8441	1.9370	1.9942	2.0456	2.0927	2.1361	2.1767	2.2148
10	v	.02	38.42	45.00	51.04	57.05	63.03	69.01	74.98	80.95
	h	161.2	1143.3	1193.9	1240.6	1287.5	1335.1	1383.4	1432.5	1482.4
(193.21)	s	.2835	1.7876	1.8595	1.9172	1.9689	2.0160	2.0596	2.1002	2.1383
14.696	v	.02	26.80	30.53	34.68	38.78	42.86	46.94	51.00	55.07
	h	180.1	1150.4	1192.8	1239.9	1287.1	1334.8	1383.2	1432.3	1482.3
(212.00)	s	.3120	1.7566	1.8160	1.8743	1.9261	1.9734	2.0170	2.0576	2.0958
20	v	.02	20.09	22.36	25.43	28.46	31.47	34.47	37.46	40.45
	h	196.2	1156.3	1191.6	1239.2	1286.6	1334.4	1382.9	1432.1	1482.1
(227.96)	s	.3356	1.7319	1.7808	1.8396	1.8918	1.9392	1.9829	2.0235	2.0618
40	v	.017	10.498	11.040	12.628	14.168	15.688	17.198	18.702	20.20
	h	236.0	1169.7	1186.8	1236.5	1284.8	1333.1	1381.9	1431.3	1481.4
(267.25)	s	.3919	1.6763	1.6994	1.7608	1.8140	1.8619	1.9058	1.9467	1.9850
60	v	.017	7.175	7.259	8.357	9.403	10.427	11.441	12.449	13.452
	h	262.1	1177.6	1181.6	1233.6	1283.0	1331.8	1380.9	1430.5	1480.8
(292.71)	s	.4270	1.6438	1.6492	1.7135	1.7678	1.8162	1.8605	1.9015	1.9400
80	v	.018	5.472		6.220	7.020	7.797	8.562	9.322	10.077
	h	282.0	1183.1		1230.7	1281.1	1330.5	1379.9	1429.7	1480.1
(312.03)	s	.4531	1.6207		1.6791	1.7346	1.7836	1.8281	1.8694	1.9079
100	v	.018	4.432		4.937	5.589	6.218	6.835	7.446	8.052
	h	298.4	1187.2		1227.6	1279.1	1329.1	1378.9	1428.9	1479.5
(327.81)	s	.4740	1.6062		1.6518	1.7085	1.7581	1.8029	1.8443	1.8829
120	v	.018	3.728		4.081	4.636	5.165	5.683	6.195	6.702
	h	312.4	1190.4		1224.4	1277.2	1327.7	1377.8	1428.1	1478.8
(341.25)	s	.4916	1.5878		1.6287	1.6869	1.7370	1.7822	1.8237	1.8625
140	v	.018	3.220		3.468	3.954	4.413	4.861	5.301	5.738
	h	324.8	1193.0		1221.1	1275.2	1326.4	1376.8	1427.3	1478.2
(353.02)	s	.5069	1.5751		1.6087	1.6683	1.7190	1.7645	1.8063	1.8451
160	v	.018	2.834		3.008	3.443	3.849	4.244	4.631	5.015
	h	335.9	1195.1		1217.6	1273.1	1325.0	1375.7	1426.4	1477.5
(363.53)	s	.5204	1.5640		1.5908	1.6519	1.7033	1.7491	1.7911	1.8301
180	v	.018	2.532		2.649	3.044	3.411	3.764	4.110	4.452
	h	346.0	1196.9		1214.0	1271.0	1323.5	1374.7	1425.6	1476.8
(373.06)	s	.5325	1.5542		1.5745	1.6373	1.6894	1.7355	1.7776	1.8167
200	v	.018	2.288		2.361	2.726	3.060	3.380	3.693	4.002
	h	355.4	1198.4		1210.3	1268.9	1322.1	1373.6	1224.8	1476.2
(381.79)	s	.5435	1.5453		1.5594	1.6240	1.6767	1.7232	1.7655	1.8048
220	v	.019	2.087		2.125	2.465	2.772	3.066	3.352	3.634
	h	364.0	1199.6		1206.5	1266.7	1320.7	1372.6	1424.0	1475.5
(389.86)	s	.5537	1.5372		1.5435	1.6117	1.6652	1.7120	1.7545	1.7939
240	v	.0186	1.9183		1.9276	2.247	2.533	2.804	3.068	3.327
	h	372.1	1200.6		1202.5	1264.5	1319.2	1371.5	1323.2	1474.8
(397.37)	s	.5631	1.5298		1.5319	1.6003	1.6546	1.7017	1.7444	1.7839
260	v	.0187	1.7748			2.063	2.330	2.582	2.827	3.067
	h	379.8	1201.5			1262.3	1317.7	1370.4	1422.3	1474.2
(404.42)	s	5719	1.5229			1.5897	1.6447	1.6922	1.7352	1.7748

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Properties of Superheated Steam—(Continued)

lbs Press Lb In² (Sat temp)	*	Sat Water	Sat Vapor	Temperature—Degrees Fahrenheit 600°	700°	800°	900°	1000°	1200°	1400°
280	v	.0188	1.6511	2.156	2.392	2.621	2.845	3.066	3.504	3.938
(411.05)	h	387.0	1202.3	1316.2	1369.4	1421.5	1473.5	1525.8	1632.1	1741.4
	s	.5801	1.5164	1.6354	1.6834	1.7265	1.7662	1.8033	1.8716	1.9337
300	v	.0189	1.5433	2.005	2.227	2.442	2.652	2.859	3.269	3.674
(417.33)	h	393.8	1202.8	1314.7	1368.3	1420.6	1472.8	1525.2	1631.7	1741.0
	s	.5879	1.5104	1.6268	1.6751	1.7184	1.7582	1.7954	1.8638	1.9260
350	v	.0191	1.3260	1.7036	1.8980	2.084	2.266	2.445	2.798	3.147
(431.72)	h	409.7	1203.9	1310.9	1365.5	1418.5	1471.1	1523.8	1630.7	1740.3
	s	.6056	1.4966	1.6070	1.6563	1.7002	1.7403	1.7777	1.8463	1.9086
400	v	.0193	1.1613	1.4770	1.6508	1.8161	1.9767	2.134	2.445	2.751
(444.59)	h	424.0	1204.5	1306.9	1362.7	1416.4	1469.4	1522.4	1629.6	1739.5
	s	.6214	1.4844	1.5894	1.6398	1.6842	1.7247	1.7623	1.8311	1.8936
500	v	.0197	.9278	1.1591	1.3044	1.4405	1.5715	1.6996	1.9504	2.197
(467.01)	h	449.4	1204.4	1298.6	1357.0	1412.1	1466.0	1519.6	1627.6	1737.9
	s	.6487	1.4634	1.5588	1.6115	1.6571	1.6982	1.7363	1.8056	1.8683
600	v	.0201	.7698	.9463	1.0732	1.1899	1.3013	1.4096	1.6208	1.8279
(486.21)	h	471.6	1203.2	1289.9	1351.1	1407.7	1462.5	1516.7	1625.5	1736.3
	s	.6720	1.4454	1.5323	1.5875	1.6343	1.6752	1.7147	1.7846	1.8476
700	v	.0205	.6554	.7934	.9077	1.0108	1.1082	1.2024	1.3853	1.5641
(503.10)	h	491.5	1201.2	1280.6	1345.0	1403.2	1459.0	1513.9	1623.5	1734.8
	s	.6925	1.4296	1.5084	1.5665	1.6147	1.6573	1.6963	1.7666	1.8299
800	v	.0209	.5687	.6779	.7833	.8763	.9633	1.0470	1.2088	1.3662
(518.23)	h	509.7	1198.6	1270.7	1338.6	1398.6	1455.4	1511.0	1621.4	1733.2
	s	.7108	1.4153	1.4863	1.5476	1.5972	1.6407	1.6801	1.7510	1.8146
1000	v	.0216	.4456	.5140	.6084	.6878	.7604	.8294	.9615	1.0893
(544.61)	h	542.4	1191.8	1248.8	1325.3	1389.2	1448.2	1505.1	1617.3	1730.0
	s	.7430	1.3897	1.4450	1.5141	1.5670	1.6121	1.6525	1.7245	1.7886
1200	v	.0223	.3619	.4016	.4909	.5617	.6250	.6843	.7967	.9046
(567.22)	h	571.7	1183.4	1223.5	1311.0	1379.3	1440.7	1499.2	1613.1	1726.9
	s	.7711	1.3667	1.4052	1.4843	1.5409	1.5879	1.6293	1.7025	1.7672
1400	v	.0231	.3012	.3174	.4062	.4714	.5281	.5805	.6789	.7727
(587.10)	h	598.7	1173.4	1193.0	1295.5	1369.1	1433.1	1493.2	1608.9	1723.7
	s	.7963	1.3454	1.3639	1.4567	1.5177	1.5666	1.6093	1.6836	1.7489
1600	v	.0239	.2548		.3417	.4034	.4553	.5027	.5906	.6738
(604.9)	h	624.1	1162.1		1278.7	1358.4	1425.3	1487.0	1604.6	1720.5
	s	.8196	1.3249		1.4303	1.4964	1.5476	1.5914	1.6669	1.7328
1800	v	.0247	.2179		.2907	.3502	.3986	.4421	.5218	.5968
(621.03)	h	648.3	1149.4		1260.3	1347.2	1417.4	1480.8	1600.4	1717.3
	s	.8412	1.3049		1.4044	1.4765	1.5301	1.5752	1.6520	1.7185
2000	v	.0257	.1878		.2489	.3074	.3532	.3935	.4668	.5352
(635.82)	h	671.7	1135.1		1240.0	1335.5	1409.2	1474.5	1596.1	1714.1
	s	.8619	1.2849		1.3783	1.4576	1.5139	1.5603	1.6384	1.7055

*v—Specific volume in cu ft/lb h—Total heat in Btu/lb s—Entropy in Btu/°F/lb

Theoretical Steam Rates, Condensing
for engines and turbines

lb per hp-hr

Initial temp °F	Exhaust pressure—In Hg abs 3.0	2.5	2.0	1.5	1.0	3.0	2.5	2.0	1.5	1.0
	150 lb gage 365.8 °F saturated steam					175 lb gage 377.4 °F saturated steam				
365.8	8.35	8.13	7.85	7.53	7.14	....	....	....	....	....
377.4	....	....	....	....	....	8.11	7.89	7.64	7.34	6.97
400	8.17	7.95	7.67	7.36	6.99	8.00	7.78	7.52	7.23	6.87
450	7.92	7.70	7.44	7.15	6.78	7.74	7.53	7.29	7.01	6.66
500	7.67	7.45	7.22	6.93	6.68	7.50	7.30	7.07	6.80	6.46
550	7.42	7.22	6.98	6.72	6.38	7 25	7.07	6.84	6.59	6.27
600	7.18	6.98	6.76	6.51	6.18	7.02	6.84	6.63	6.39	6.08
650	6.95	6.76	6.55	6.31	6.00	6.79	6.62	6.43	6.19	5.90
700	6.72	6.53	6.34	6.11	5.82	6.58	6.41	6.23	6.00	5.72
	200 lb gage 387.8°F saturated steam					250 lb gage 406°F saturated steam				
387.8	7.92	7.71	7.46	7.19	6.84	....	....	....	....	....
406.0	....	....	....	....	....	7.62	7.43	7.20	6.95	6.62
450	7.61	7.41	7.17	6.90	6.57	7.39	7.20	6.99	6.74	6.43
500	7.35	7.16	6.95	6.68	6.37	7.15	6.97	6.76	6.52	6.22
550	7.12	6.94	6.73	6.48	6.18	6.92	6.75	6.55	6.32	6.04
600	6.90	6.72	6.52	6.29	5.99	6.69	6.53	6.35	6.13	5.85
650	6.67	6.51	6.32	6.10	5.81	6.49	6.33	6.15	5.94	5.68
700	6.46	6.30	6.12	5.91	5.64	6.28	6.13	5.96	5.76	5.51
750	6.25	6.10	5.93	5.73	5.47	6.08	5.94	5.77	5.58	5.34
	300 lb gage 421.7°F saturated steam					400 lb gage 448.1°F saturated steam				
421.7	7.39	7.21	7.01	6.76	6.47	....	....	....	....	....
448.1	....	....	....	....	....	7.07	6.91	6.72	6.50	6.23
450	7.23	7.06	6.86	6.62	6.33	....	....	....	....	....
500	6.99	6.83	6.63	6 40	6.12	6.78	6.63	6.46	6.25	5.98
550	6.76	6.61	6.42	6 20	5.93	6.63	6 40	6.23	6.04	5.79
600	6.55	6.40	6.21	6.01	5 75	6.34	6.19	6.03	5.84	5.60
650	6.33	6.20	6.02	5 82	5 58	6.13	5.99	5.84	5.66	5.43
700	6.14	5.99	5.84	5.65	5.41	5.94	5.81	5.67	5.49	5.26
750	5.94	5.81	5.66	5.48	5.25	5.75	5.63	5.49	5.32	5.11
800	5.76	5.63	5.49	5.31	5.09	5.57	5.45	5.32	5.16	4.96
850	5.57	5.45	5.32	5.15	4.94	5.40	5.28	5.16	5.01	4.82
	600 lb gage 488.8°F saturated steam					800 lb gage 520.3°F saturated steam				
600	6.10	5.98	5.83	5 66	5.45	....	....	....	....	....
650	5.90	5 78	5.64	5.47	5.27	5.78	5.67	5.54	5 38	5.19
700	5.70	5.59	5.46	5.30	5.10	5.58	5.47	5 35	5.20	5 01
750	5.52	5.41	5.29	5.14	4.94	5.39	5.28	5.17	5.03	4 85
800	5.35	5.24	5.12	4.98	4.80	5.21	5.12	5.01	4 87	4 70
850	5.18	5.08	4.97	4.83	4.65	5.05	4.96	4.85	4.73	4 57
900	5.02	4.93	4.82	4.69	4.52	4.89	4.80	4.70	4.58	4.43
950	4.86	4.78	4.67	4.55	4.39	4.74	4.66	4.57	4 45	4 30
1000	4.71	4.63	4.53	4.42	4.27	4.60	4.53	4.43	4.32	4.18

Theoretical Steam Rates, Condensing for engines and turbines

lb per hp-hr

Initial Temp °F	Exhaust pressure—In Hg abs									
	3.0	2.5	2.0	1.5	1.0	3.0	2.5	2.0	1.5	1.0
	1000 lb gage 546.4°F saturated steam					1200 lb gage 568.8°F saturated steam				
700	5.51	5.41	5.28	5.15	4.97	....	....	....	....	....
750	5.31	5.21	5.10	4.97	4.80	5.27	5.17	5.07	4.94	4.77
800	5.14	5.04	4.93	4.81	4.65	5.08	4.99	4.89	4.77	4.62
850	4.97	4.88	4.78	4.65	4.50	4.91	4.83	4.73	4.61	5.46
900	4.81	4.73	4.63	4.52	4.37	4.76	4.67	4.58	4.47	4.33
950	4.67	4.59	4.49	4.38	4.24	4.61	4.53	4.44	4.33	4.20
1000	4.52	4.45	4.36	4.26	4.12	5.47	4.39	4.31	4.21	4.08

Theoretical Steam Rates, Non-Condensing

lb per hp-hr

100 lb gage 337.9°F saturated steam

Exhaust press lb/sq in gage	Initial temperature, °F									
	337.9	350	400	450	500	550	600	650	700	750
	Initial superheat, °F									
	0	12.1	62.1	112	162	212	262	312	362	412
0	16.9	16.8	16.2	15.6	15.0	14.3	13.6	12.9	12.3	11.8
5	19.4	19.3	18.6	17.8	17.0	16.2	15 3	14.6	13.9	13.3
10	22.0	21.8	21.0	20.1	19.1	18.1	17.2	16.3	15 6	14.9
15	24.7	24.5	23.6	22.4	21.2	20.2	19.1	18.2	17.3	16.6
20	27.7	27.4	26.3	25.1	23.7	22.4	23.2	20.2	19.3	18.4
25	31.0	30.7	29.4	27.9	26.2	24.8	26.5	22.5	21.4	20 5
30	34.6	34.3	32.8	30.9	29.1	27.6	21.2	24.9	23.8	22.7
35	38.7	38.4	36.7	34.4	32.4	30.6	29.1	27.8	26.5	25.3
40	43.4	43.0	41.1	38.5	36.3	34.3	32.6	31.1	29.6	28.2
45	48.9	48.5	46.2	43.2	40.6	38.5	36.6	34.9	33.4	31.8
50	....	....	52.3	48.9	46.1	43.5	41.3	39.5	37.6	35.8
55	....	....	....	....	52.5	49.7	47.2	45.0	42.8	40.9
60	....	....	....	....	....	....	....	51.9	49.5	47.2

Theoretical Steam Rates, Non-Condensing
for engines and turbines
lb per hp-hr

150 lb gage 365.8°F saturated steam

Exhaust press lb/sq in gage	Initial temperature, °F									
	365.8	400	450	500	550	600	650	700	750	800
	Initial superheat, °F									
	0	34.2	84.2	134	184	234	284	334	384	434
0	14.4	14.1	13.6	13.1	12.5	12.0	11.5	11.0	10.5	10.0
5	16.2	15.7	15.1	14.6	13.9	13.3	12.7	12.1	11.5	11.0
10	17.9	17.4	16.7	16.0	15.3	14.6	13.8	13.2	12.6	12.1
15	19.6	19.1	18.3	17.5	16.6	15.8	15.0	14.3	13.7	13.1
20	21.3	20.8	19.9	19.0	18.0	17.1	16.2	15.5	14.8	14.1
25	23.2	22.6	21.6	20.5	19.4	18.4	17.5	16.7	15.9	15.3
30	25.0	24.4	23.3	22.1	20.9	19.2	18.8	18.0	17.2	16.4
35	27.1	26.4	25.2	23.8	22.5	21.3	20.2	19.3	18.5	17.7
40	29.3	28.5	27.1	25.6	24.2	23.0	21.8	20.8	19.9	19.0
45	31.7	30.8	29.3	27.7	26.0	24.7	23.5	22.3	21.4	20.5
50	34.3	33.3	31.6	29.7	28.0	26.5	25.2	24.0	22.9	22.0
60	40.2	39.0	36.8	34.6	32.6	30.9	29.3	28.0	26.8	25.6
70	47.3	45.8	43.2	40.5	38.2	36.2	34.3	32.8	31.4	30.1
80	....	....	51.2	48.1	45.3	42.9	40.8	38.8	37.2	35.6
90	....	....	....	....	....	51.7	49.2	47.0	44.9	43.0

200 lb gage 387.8°F saturated steam

Exhaust press lb/sq in gage	Initial temperature, °F									
	387.8	400	450	500	550	600	650	700	750	800
	Initial superheat, °F									
	0	12.2	62.2	112	162	212	262	312	362	412
0	13.1	13.0	12.5	12.0	11.5	11.1	10.6	10.2	9.7	9.3
5	14.4	14.3	13.7	13.2	12.7	12.1	11.6	11.1	10.6	10.1
10	15.7	15.6	15.0	14.3	13.8	13.2	12.5	12.0	11.4	10.9
15	17.0	16.9	16.2	15.5	14.9	14.1	13.5	12.8	12.2	11.7
20	18.3	18.1	17.4	16.6	15.9	15.1	14.4	13.7	13.1	12.5
25	19.6	19.4	18.6	17.8	17.0	16.1	15.3	14.6	13.9	13.3
30	20.9	20.8	19.9	19.0	18.0	17.1	16.2	15.4	14.7	14.1
35	22.3	22.1	21.1	20.2	19.1	18.1	17.2	16.3	15.6	15.0
40	23.8	23.6	22.5	21.4	20.3	19.2	18.2	17.3	16.5	15.8
50	26.8	26.5	25.3	24.1	22.7	21.4	20.4	19.4	18.5	17.7
60	30.1	29.9	28.5	27.0	25.4	24.1	22.8	21.7	20.7	19.8
70	34.0	33.8	32.0	30.2	28.4	26.9	25.5	24.3	23.2	22.2
80	38.3	38.0	36.1	33.9	31.9	30.2	28.6	27.3	26.0	24.9
90	43.5	43.1	40.9	38.3	35.9	34.0	32.3	30.7	29.3	28.1
100	49.6	49.2	46.5	43.3	40.7	38.5	36.6	34.8	33.3	31.8
110	....	....	....	49.4	46.5	44.1	41.8	39.8	38.0	36.5

Theoretical Steam Rates, Non-Condensing for engines and turbines

250 lb gage **406.0°F saturated steam**

Exhaust press lb/sq in gage	Initial temperature, °F									
	406	450	500	550	600	650	700	750	800	850
	Initial superheat, °F									
	0	44	94	144	194	244	294	344	394	444
0	12.1	11.7	11.3	10.9	10.4	10.0	9.6	9.2	8.8	8.5
5	13.3	12.8	12.3	11.8	11.4	10.9	10.4	10.0	9.6	9.2
10	14.4	13.9	13.3	12.8	12.3	11.7	11.2	10.7	10.2	9.8
15	15.4	14.9	14.3	13.7	13.1	12.5	11.9	11.4	10.9	10.4
20	16.5	15.9	15.3	14.6	13.9	13.2	12.6	12.0	11.5	11.0
25	17.5	16.9	16.2	15.4	14.7	14.0	13.3	12.7	12.1	11.6
30	18.5	17.9	17.1	16.3	15.5	14.7	14.0	13.4	12.8	12.2
40	20.7	19.9	19.0	18.1	17.2	16.3	15.5	14.7	14.1	13.5
50	22.9	22.1	21.0	19.9	18.9	17.9	17.0	16.2	15.5	14.6
60	25.3	24.4	23.2	21.9	20.7	19.6	18.6	17.8	17.0	16.3
70	27.9	26.8	25.4	24.0	22.7	21.5	20.4	19.5	18.6	17.8
80	30.7	29.5	27.9	26.3	24.8	23.6	22.4	21.3	20.4	19.5
90	33.8	32.5	30.7	28.8	27.2	25.8	24.5	23.3	22.3	21.4
100	37.3	35.8	33.8	31.7	29.8	28.3	26.9	25.6	24.5	23.5
120	45.7	43.7	41.0	38.5	36.3	34.4	32.7	31.2	29.8	28.6

300 lb gage **421.7°F saturated steam**

Exhaust press lb/sq in gage	Initial temperature, °F									
	421.7	450	500	550	600	650	700	750	800	850
	Initial superheat, °F									
	0	28.3	78.3	128	178	228	278	328	378	428
0	11.5	11.2	10.8	10.4	10.0	9.6	9.2	8.9	8.5	8.2
5	12.5	12.2	11.7	11.3	10.8	10.4	10.0	9.6	9.1	8.8
10	13.5	13.2	12.6	12.1	11.6	11.1	10.6	10.2	9.7	9.3
15	14.4	14.0	13.4	12.9	12.3	11.8	11.3	10.8	10.3	9.9
20	15.3	14.9	14.3	13.7	13.1	12.5	11.9	11.3	10.8	10.4
30	17.0	16.5	15.8	15.1	14.4	13.7	13.1	12.5	11.9	11.4
40	18.7	18.3	17.4	16.6	15.8	15.0	14.3	13.6	13.0	12.4
50	20.5	20.0	19.1	18.1	17.3	16.3	15.5	14.8	14.1	13.5
60	22.4	21.8	20.7	19.7	18.7	17.7	16.8	16.0	15.3	14.6
80	26.5	25.7	24.5	23.1	21.8	20.6	19.6	18.7	17.9	17.1
100	31.2	30.2	28.7	27.0	25.4	24.1	22.8	21.8	20.8	19.9
120	36.6	35.6	33.5	31.5	29.7	28.1	26.8	25.5	24.4	23.3
140	43.5	42.2	39.7	37.1	35.0	33.1	31.4	30.1	28.7	27.4
160	52.3	50.4	47.2	44.1	41.6	39.4	37.3	35.6	34.2	32.6
180	....	....	....	....	50.5	47.7	45.3	43.1	41.3	39.6

Theoretical Steam Rates, Non-Condensing
for engines and turbines

400 lb gage — 448.1°F saturated steam

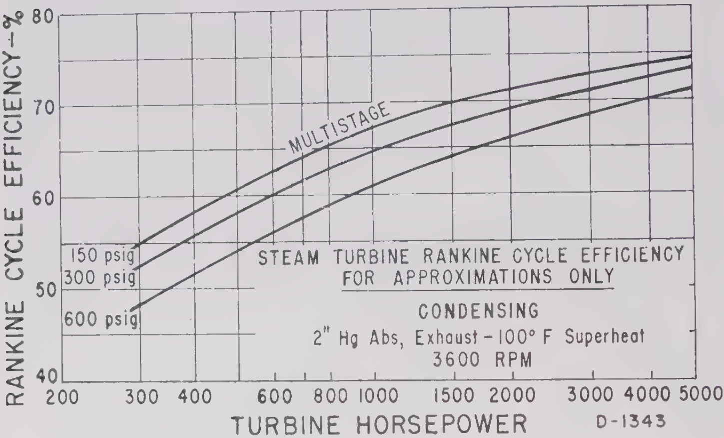
Exhaust press lb/sq in gage	Initial temperature, °F									
	448.1	500	550	600	650	700	750	800	850	900
	Initial superheat, °F									
	0	51.9	102	152	202	252	302	352	402	452
0	10.6	10.2	9.8	9.4	9.0	8.7	8.4	8.0	7.7	7.4
5	11.5	11.0	10.5	10.1	9.7	9.3	8.9	8.6	8.2	7.9
10	12.2	11.7	11.2	10.8	10.3	9.9	9.5	9.1	8.7	8.4
20	13.7	13.0	12.5	11.9	11.4	10.9	10.4	10.0	9.6	9.2
30	15.0	14.3	13.7	13.1	12.5	11.9	11.4	10.8	10.4	9.9
40	16.3	15.6	14.8	14.1	13.5	12.8	12.2	11.7	11.2	10.7
50	17.6	16.8	16.0	15.2	14.5	13.8	13.1	12.5	11.9	11.4
60	18.9	18.0	17.2	16.3	15.5	14.7	14.0	13.3	12.8	12.2
80	21.7	20.6	19.6	18.5	17.5	16.6	15.8	15.1	14.4	13.8
100	24.7	23.4	22.2	20.9	19.7	18.7	17.8	17.0	16.2	15.6
120	27.9	26.5	25.0	23.5	22.2	21.0	20.0	19.1	18.2	17.5
140	31.6	29.9	28.1	26.4	24.9	23.6	22.4	21.4	20.5	19.6
160	35.8	33.8	31.7	29.7	28.0	26.5	25.2	24.1	23.0	22.1
180	40.7	38.4	35.8	33.5	31.7	30.0	28.5	27.2	26.0	25.0
200	46.6	43.7	40.6	38.1	36.0	34.1	32.4	30.9	29.6	28.4

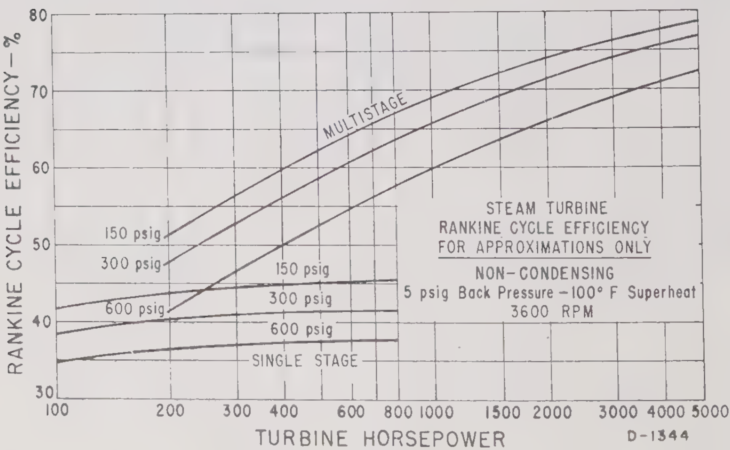
600 lb gage — 488.8°F saturated steam

Exhaust press lb/sq in gage	Initial temperature									
	575	600	650	700	750	800	850	900	950	1000
	Initial superheat, °F									
	86.2	111	161	211	261	311	361	411	461	511
0	8.9	8.7	8.4	8.1	7.8	7.5	7.2	6.9	6.7	6.4
10	10.0	9.8	9.4	9.1	8.7	8.3	8.0	7.7	7.4	7.1
20	11.0	10.8	10.3	9.9	9.5	9.1	8.7	8.3	8.0	7.7
30	11.9	11.6	11.1	10.6	10.1	9.7	9.3	8.9	8.5	8.2
40	12.8	12.4	11.9	11.3	10.8	10.3	9.9	9.4	9.1	8.7
50	13.5	13.2	12.6	12.0	11.4	10.9	10.4	10.0	9.6	9.2
60	14.3	14.0	13.3	12.7	12.1	11.5	11.0	10.5	10.0	9.7
80	15.9	15.5	14.7	14.0	13.3	12.6	12.0	11.5	11.0	10.6
100	17.5	17.1	16.2	15.3	14.5	13.8	13.1	12.6	12.1	11.6
125	18.3	19.0	18.0	17.0	16.1	15.3	14.6	14.0	13.4	12.8
150	21.8	21.1	19.9	18.7	17.8	16.9	16.1	15.4	14.8	14.2
175	24.1	23.4	21.9	20.6	19.6	18.7	17.8	17.0	16.3	15.7
200	26.8	25.9	24.1	22.8	21.6	20.5	19.6	18.7	18.0	17.3
250	32.7	31.6	29.5	27.8	26.3	25.0	23.9	22.9	22.0	21.1
300	40.5	39.0	36.5	34.4	32.5	31.0	29.6	28.3	27.1	26.1

Pages 153 to 157 calculated from "Theoretical Steam Rate Tables" by J. H. Keenan and F. G. Keyes, published by American Society of Mechanical Engineers, 1938.

Approximate Turbine Efficiency—Rankine Cycle





SUPERHEAT CORRECTIONS TO CURVE RANKINE CYCLE EFFICIENCY

Type of Turbine	Single-Stage	Multi-stage	
	Non-condensing	Non-condensing	Condensing
Correction Method	Add or Subtract To or From RCE	Multiply	Multiply
Superheat			
0°F	add 0.6	0.963	0.977
100°F	—	1.000	1 000
200°F	Subtract 0.6	1.012	1.018
300°F	Subtract 1.2	1.015	1.034

MULTIPLIERS FOR SPEEDS OTHER THAN 3600 RPM MULTI-STAGE TURBINES ONLY

	Non-condensing				Condensing			
RPM	3000	5000	7500	10,000	3600	5000	7500	10,000
BHP								
500	1.000	1.030	1.036	1.018	1.000	1.000	1.000	1.000
1000	1.000	1.013	1.006	0.982	1 000	1.000	1.000	1.000
2000	1.000	1.001	0.980	0 940	1.000	1.000	1.000	0.957
3000	1.000	0.997	0.968	0.920	1.000	1.000	0.984	0.929
5000	1.000	0.994	0.959	0.902	1.000	1.000	0.955	0.895

EFFICIENCY

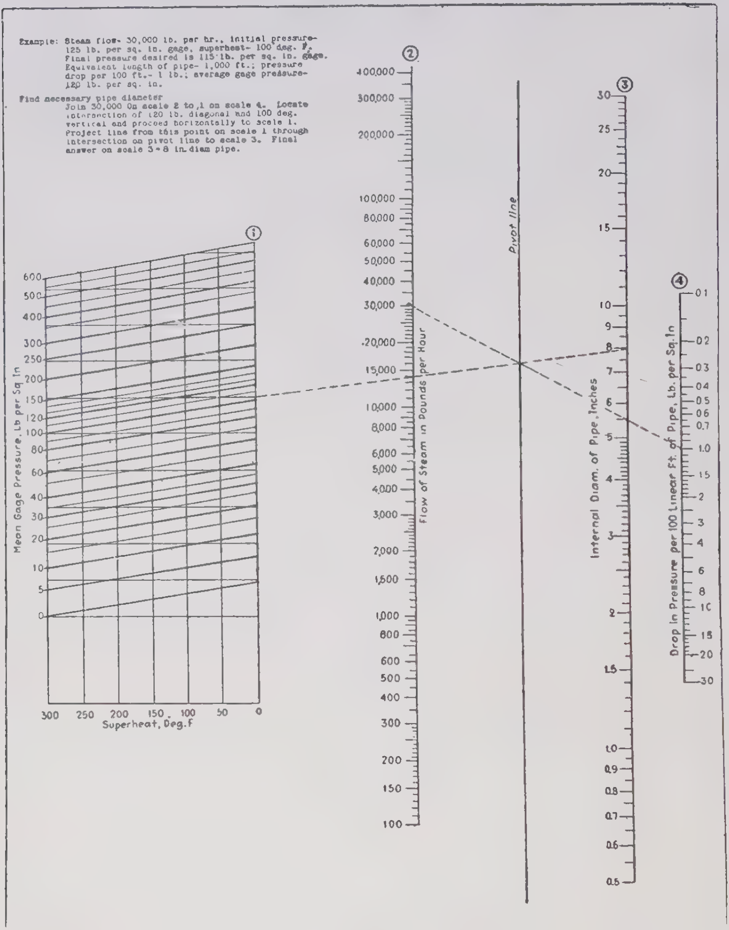
Page 158 gives approximate Rankine cycle efficiencies (RCE) for single-stage and multi-stage turbines at various ratings and steam pressures. These data may be used only for rough estimating. There is considerable variance between manufacturers for a given rating and condition, some offering a higher efficiency, some lower, depending upon how the conditions match a particular frame size or design.

Although very large turbines are used for certain types of compressors, a limit of 5000 hp has been chosen for these data since it was felt this encompassed the majority of compressor drives where such data would be used. It is to be expected that larger units would have higher efficiencies. For example, a 25,000 hp, 3600 rpm turbine at 600 psig, 750°F and 5″ Hg abs. exhaust, would have an efficiency of about 82%.

Single-stage turbines often operate at some back pressure. The curves are based on 5 psig back pressure. For back pressures to 50 psig multiply RCE from the curves by (1 + 0.25) (Back Pressure − 5). This, however, does not apply for 150 psig steam above 30 psig back pressure.

Condensing turbines show a small increase in RCE for higher absolute exhaust pressure (lower vacuums), but it is not significant for the purpose of these curves.

Pressure Drop in Steam Piping



Based on Gutermuth formula

$$W = 324\sqrt{Pcd^5}$$

in which

W = Steam flow, lb. per hr.
P = Pressure drop per 100 linear feet of pipe, lb. per sq. in.
c = Density, lb., per cu. ft.
d = Actual internal pipe diam., in.

Reproduced from chart prepared by M. E. Cowan for "Power"

Friction Loss in Pipe Fittings in terms of equivalent feet of straight pipe.

These data may be applied to any liquid or gas

Nominal pipe Size Dn Std. Wt.	Actual inside diam. in.	Gate Valve FULL OPEN	45° Elbow	Long-sweep elbow or run of Std tee	Std elbow or run of tee reduced ½	Std tee thru side outlet	Close return bend	Swing check valve FULL OPEN	Angle Valve FULL OPEN	Globe Valve FULL OPEN	Equivalent Resistance of Std. Wt. Welding Elbows Length of Straight Pipe (Feet)[1*] — 90° Elbows: Short Radius R/DN=1	90° Elbows: Long Radius R/DN=1½	45° Elbows: Short Radius R/DN=1	45° Elbows: Long Radius R/DN=1½
Resistance factor		.19	.42	.6	.9	1.8	2.2	2.3	5.	10.				
½	.622	.35	.78	1.11	1.7	3.3	4.1	4.3	9.3	18.6	‡	0.68	‡	0.44
¾	.824	.44	.97	1.4	2.1	4.2	5.1	5 3	11.5	23.1	‡	0.91	‡	0.58
1	1.049	.56	1.23	1.8	2.6	5.3	6.5	6.8	14.7	29.4	1.6	1.15	1.01	0.74
1¼	1.380	.74	1.6	2.3	3.5	7.0	8.5	8.9	19.3	38.6	2.1	1.5	1.33	0.98
1½	1.610	.86	1.9	2.7	4.1	8.1	9.9	10.4	22.6	45.2	2.4	1.8	1.6	1.14
2	2.067	1.10	2.4	3.5	5.2	10.4	12.8	13.4	29	58	3.1	2.3	2.0	1.5
2½	2.469	1.32	2.9	4.2	6.2	12.4	15.2	15.9	35	69	3.7	2.7	2.4	1.7
3	3.068	1.6	3.6	5.2	7.7	15.5	18.9	19.8	43	86	4.7	3.4	3.0	2.2
4	4.026	2.1	4.7	6.8	10.2	20.3	24.8	26.0	57	113	6.1	4.4	3.9	2.9
5	5.047	2.7	5.9	8.5	12.7	25.4	31	33	71	142	7.7	5.6	4.9	3.6
6	6.065	3.2	7.1	10.2	15.3	31	37	39	85	170	9.2	6.7	5.9	4.3
7	7.024	3.7	8.3	11.8	17.7	35	43	45	98	197	‡‡	‡‡	‡‡	‡‡
8	7.981	4.3	9.4	13.4	20.2	40	49	52	112	224	12.1	8.8	7.7	5.7
10	10.020	5.3	11.8	16.9	25.3	51	62	65	141	281	15.2	11.0	9.7	7.1
12	12.000	6.4	14.1	20 2	30	61	74	77	168	336	18.2	13.2	11.6	8.5
14		7.5	16.5	23.5	35	71	86	90			20.1	14.6	12.8	9.4
16		8.5	18.8	26.9	40	81	99	104			23.1	16.8	14.7	10.8
18		9.6	21.2	30	45	91	111	116			26.2	19.0	16.7	12.2
20		10.7	23.5	34	50	101	123	129			29	21.2	18.6	13.6
24		12.8	28.2	40	61	121	148	155			35	25.6	22.5	16.5
30		16.0	35.3	50	76	151	185	193			44	32	28.3	20.7
36		19.2	42.4	61	91	181	222	232			53	39	34	25.0
42		22.4	49.4	71	106	212	259	271			63	45	40	29.2
48		25.6	57.6	81	121	242	296	310			72	52	46	33

Data on fittings based on information published by Crane Co.
*For 180° bend multiply values for 90° bend by 1.34.
Data are based on Fanning coefficient of 0.006, as taken from Chart No. 18 of Catalog 211 of Tube Turns, Inc.
‡Short Radius elbows, R/DN=1, not made in this size and weight.
‡‡Not made in this size.

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Steam flow through pipes at various abs press in lb per hr based on 100 ft per sec velocity

Pipe		Absolute pressure in inches of mercury														
Nom size	Area sq ft	Atmos press	10″	8″	6″	5″	4″	3.5″	3″	2.5″	2″	1.5″	1.25″	1″	.75	.50
1½″	0.01415	190	68	55	40	36	29	25	22	19	15	11	10	8	6	4
2″	0.02331	313	112	91	65	59	48	42	36	30	25	19	16	13	10	7
2½″	0.03322	445	159	130	93	83	68	60	52	44	35	27	23	18	14	10
3″	0.0513	690	246	200	143	129	104	92	80	67	54	41	35	28	21	15
4″	0.0884	1190	425	346	246	222	180	159	137	116	94	71	60	48	37	25
5″	0.1388	1860	665	543	388	350	282	250	215	182	147	112	94	76	58	40
6″	0.2006	2700	963	785	560	505	408	361	312	262	212	162	136	110	84	57
8″	0.3475	4660	1670	1360	970	875	706	625	540	455	368	280	236	190	145	99
10″	0.5475	7350	2630	2140	1530	1380	1110	985	850	716	580	440	372	300	229	157
12″	0.7855	10600	3770	3080	2200	1980	1600	1410	1220	1030	831	634	534	430	329	224
14″	1.069	12900	5130	4180	2980	2690	2180	1920	1660	1400	1135	860	725	585	446	305
16″	1.396	17000	6700	5450	3900	3520	2840	2510	2170	1820	1480	1120	948	762	584	398
18″	1.767	21800	8480	6900	4930	4450	3600	3180	2750	2310	1880	1420	1200	965	740	505
20″	2.182	27200	10500	8550	6100	5500	4450	3930	3400	2860	2320	1710	1480	1200	914	624
24″	3.142	39600	15100	12300	8760	7900	6400	5650	4890	4100	3330	2520	2140	1720	1320	898
30″	4.909	62700	23600	19200	13700	12400	10000	8850	7630	6420	5200	3930	3340	2690	2060	1400
36″	7.069	91000	34000	27600	19700	17800	14400	12700	11000	9250	7500	5690	4800	3860	2960	2020
42″	9 621	125000	46200	37600	26800	24200	19600	17300	14900	12600	10200	7740	6540	5250	4020	2750
48″	12.57	163000	60300	49000	35000	31600	25600	22600	19500	16400	13300	10100	8540	6860	5250	3590
54″	15.90	208000	76400	62200	44400	40000	32400	28600	24800	20800	16900	12800	10800	8700	6650	4550
60″	19.63	257000	94400	76900	54800	49500	40000	35400	30600	25700	20800	15800	13300	10750	8210	5600
66″	23.76	312000	114000	92900	66200	59800	48400	42800	36900	31000	25200	19100	16100	13000	9940	6780
72″	28.27	372000	136000	110000	79000	71100	57600	51000	44000	37000	30000	22800	19200	15500	11800	8080

*Area denotes transverse internal area of pipe

Sizes up to 12″ are std wrought pipe

Sizes above 12″ are Class A cast iron pipe

Steam Condensers

Steam condensers are a form of heat exchanger in which steam is reduced to the liquid state by cooling either through direct contact with cold water (barometric or jet condensers) or through contact with water-cooled tubing (surface condensers). A vacuum is maintained in the condenser by removing any noncondensible gases with an air pump or with steam jets.

Surface condensers permit the recovery of the condensate, while in barometric or jet condensers the condensate is mixed with the cooling water and lost.

The temperature of the available cold water is the main factor in determining the temperature and vapor pressure at which condensation will take place, hence the degree of vacuum which can be produced. Vacuum is measured either as pressure below atmospheric pressure expressed in inches or mm of Mercury referred to a 30 in. Barometer, or as the absolute pressure in inches or mm Hg.

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With various circulating water temperatures the usual range of design vacuums for surface condensers serving steam turbines is as follows: (For engine service the abs press is higher, usually 3.5″ or 4″).

Inlet water—T_1	Design abs press	Steam temp—T_s	Temp diff TD...(T_s—T_1)
50° F.	1.0″ to 1.5″	79.0° F. 91.7	29.0° F. 41.7
60	1.25″ to 1.75″	85.9 96.7	25.9 36.7
70	1.5″ to 2.0″	91.7 101.1	21.7 31.1
75	1.75″ to 2.0″	96.7 101.1	21.7 26.1
80	2.0″ to 2.25″	101.1 105.0	21.1 25.0
85	2.25″ to 2.5″	105.0 108.6	20.0 23.6

For the usual design or operating range, the capacity of any condenser with a given quantity and temperature of circulating water is directly proportional to the temperature difference (TD) between the steam and the inlet water. With efficient design it is possible to handle 10 to 15 or 20 lb of steam per sq ft of tube surface, depending on the desired vacuum and the quantity of circulating water.

Steam Condensers (Continued)

The quantity of circulating water required for a given steam load is determined by the possible temperature rise (TR) of the water, which in turn is a function of the temperature difference (TD) between the steam and the inlet water (approx. 40% to 60% for single pass condensers, and 55% to 75% or 80% for two pass condensers, depending principally on the tube size and tube length). The relation between quantity of circulating water in gallons per min. (Q) and TR irrespective of condenser size, type or design is as follows:

Steam condensed in lb/hr $\times$ Btu/lb = Q $\times$ 500 $\times$ TR.

The heat of condensation which is the quantity of heat absorbed by the circulating water is generally assumed as 950 Btu/lb for turbine service or 1000 Btu/lb for engine service. In special cases where the steam to be condensed is dry or superheated it will be higher.

The overall rate of heat transfer (usually expressed as a coefficient "U") is the Btu per sq. ft. of tube surface per hour per degree logarithmic mean temperature difference (LMTD). "U" depends on such factors as tube size, tube cleanliness, water velocity, water temperature, and condenser efficiency. Curves for the determination of this heat transfer coefficient are given on page 171. These curves are based on 70° F. water temperature and No. 18 BWG clean, oxide free Admiralty tubes. Correction curves and factors are given for variations in condensing water temperature, tube thickness and tube material.

Additional curves on page 172 show the limiting factors of light load operation for steam condensers.

For surface condensers the logarithmic mean temperature difference (LMTD) is as follows:

$$\text{LMTD} = \frac{\text{TR}}{\log_e\left(\dfrac{\text{TD}}{\text{TD} - \text{TR}}\right)}$$

where TD = Initial temperature difference between steam and inlet water
TR = Temperature rise between inlet water and discharge water

For more general cases of heat transfer where the temperature of the hot medium falls see page 168-9.

The steam tables, pages 140 to 152 give the properties of steam at various vacuums or absolute pressures and the following pages include useful information applying to surface condensers or steam condensers in general.

Surface Condenser Tube Data

	Thickness		Tube Size			
	In	BWG	⅝"	¾"	⅞"	1"
Outside dia—in			.625	.750	.875	1.000
Inside dia—in	.065	No. 16	.495	.620	.745	.870
	.058	No. 17	.509	.634	.759	.884
	.049	No. 18	.527	.652	.777	.902
	.035	No. 20	.555	.680	.805	.930
Surface—(outside) sq ft per lineal ft			.16362	.19635	.22907	.26180
Length in ft. for 1 sq ft surface			6.1116	5.093	4.3654	3.8197
Water quantity gpm at 1 ft per sec velocity		No. 16	.60	.94	1.36	1 85
		No. 17	.63	.98	1.41	1.91
		No. 18	.68	1.04	1.48	1.99
		No. 20	.75	1.13	1.59	2.12
WEIGHT OF TUBE* Lb per lineal foot		No. 16	.444	.543	.642	.741
		No. 17	.401	.489	.578	.666
		No. 18	.344	.419	.494	.568
		No. 20	.252	.306	.358	.412
Lb per sq ft of surface		No. 16	2.71	2.77	2.80	2.83
		No. 17	2.45	2.49	2.52	2.54
		No. 18	2.10	2.13	2.16	2.17
		No. 20	1.54	1.56	1.56	1.57
WEIGHT OF WATER IN TUBE Lb water per lineal foot		No. 16	.083	.131	.189	.257
		No. 17	.088	.137	.196	.266
		No. 18	.094	.144	.205	.276
		No. 20	.105	.157	.220	.294
Lb water per sq ft of surface		No. 16	.51	.67	.83	.98
		No. 17	.54	.70	.86	1.02
		No. 18	.57	.73	.90	1.05
		No. 20	.64	.80	.96	1.12

*Note:—Above weights are for Admiralty Metal. Weights are based on nominal I.D nominal wall thickness, and a lot weight tolerance of plus 5 per cent as specified in A.S.T.M designation B111.

For other materials multiply by following factors

Copper................1.049

Arsenical Copper.......1.049

Copper-nickel, 70-30....1.049

Copper-nickel, 80-20....1.049

Copper-nickel, 90-10....1.049

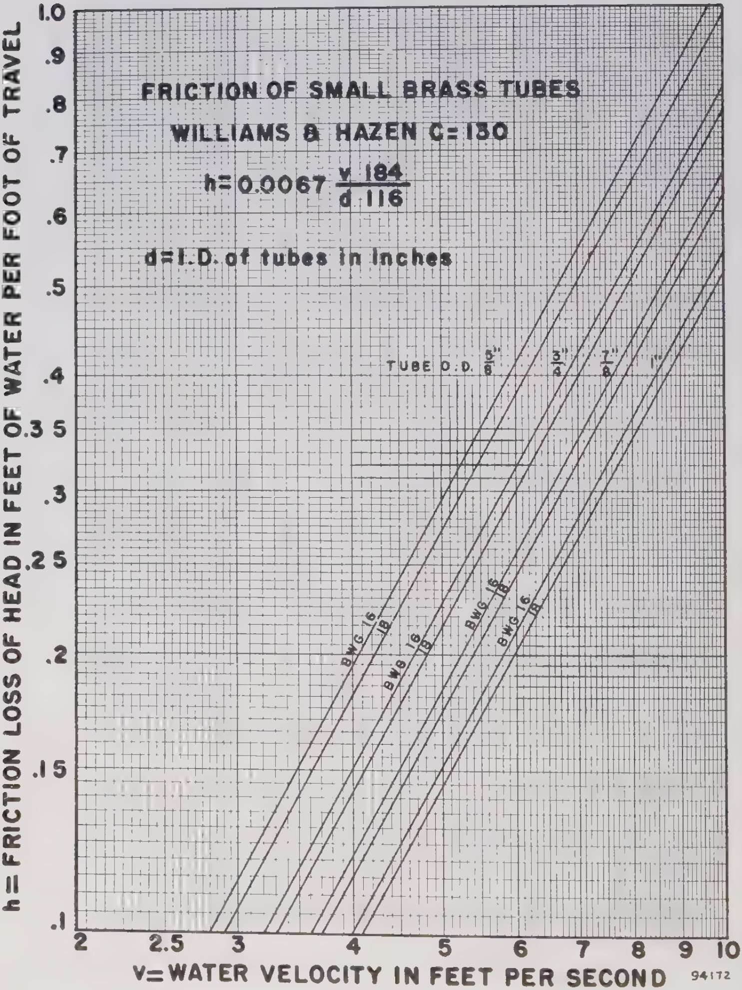
Red brass.............1.026

Muntz Metal........... .984

Aluminum Brass....... .977

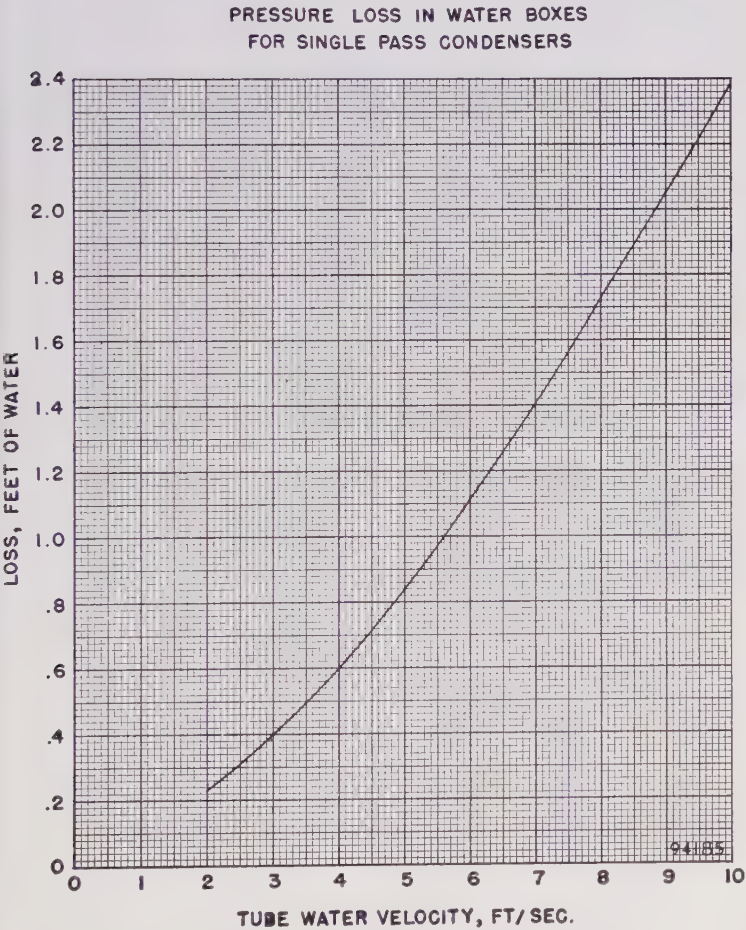
Aluminum Bronze...... .958

Friction Loss through Condenser Tubes



Reproduced from "Standards for Steam Surface Condensers," Standards of Heat Exchange Institute.

Friction Loss in Water Boxes



Reproduced from "Standards for Steam Surface Condensers," Standards of Heat Exchange Institute.

Note:—For multi-pass condensers multiply curve values by the number of water passes.

General Heat Transfer Cases

Nomenclature:

$$\text{LMTD} = \text{logarithmic mean temperature difference} = \frac{\text{GTD} - \text{LTD}}{\text{Loge}\ \dfrac{\text{GTD}}{\text{LTD}}}$$

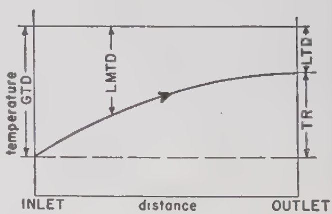
TR = temperature rise of cold substance.
TF = temperature fall of hot substance.
ITD = initial temperature difference between hot and cold substances.
FTD = final temperature difference between hot and cold substances.
GTD = greatest temperature difference.
LTD = least temperature difference.

Case I—Hot substance giving up heat with temperature remaining constant to a cold substance absorbing heat with rising temperature.

GTD = ITD

LTD = ITD–TR

This case includes:—steam condensers, ammonia condensers, and boiler feed water heaters.

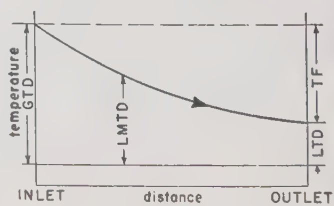


Case II—Hot substance giving up heat with falling temperature to a cold substance absorbing heat with temperature remaining constant.

GTD = ITD

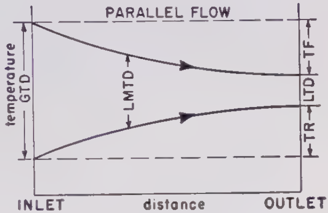
LTD = ITD–TF

This case includes:—steam boilers, ammonia brine coolers, ammonia direct expansion coils in cold storage rooms, evaporator with hot liquid coils or jacket.



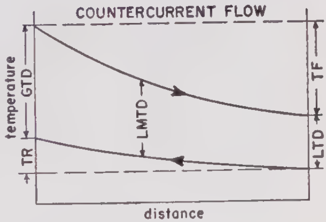
General Heat Transfer Cases (Cont)

Case III—Two substances both changing temperature, one giving up heat with falling temperature to the other absorbing heat with rising temperature, **parallel flow.**



Case IV—Two substances both changing temperature, one giving up heat with falling temperature to the other absorbing heat with rising temperature, **countercurrent flow.**

Cases III & IV include:—steam superheaters and economizers, brine coils in cold storage rooms, compressor intercoolers, cylinder jackets and oil coolers.



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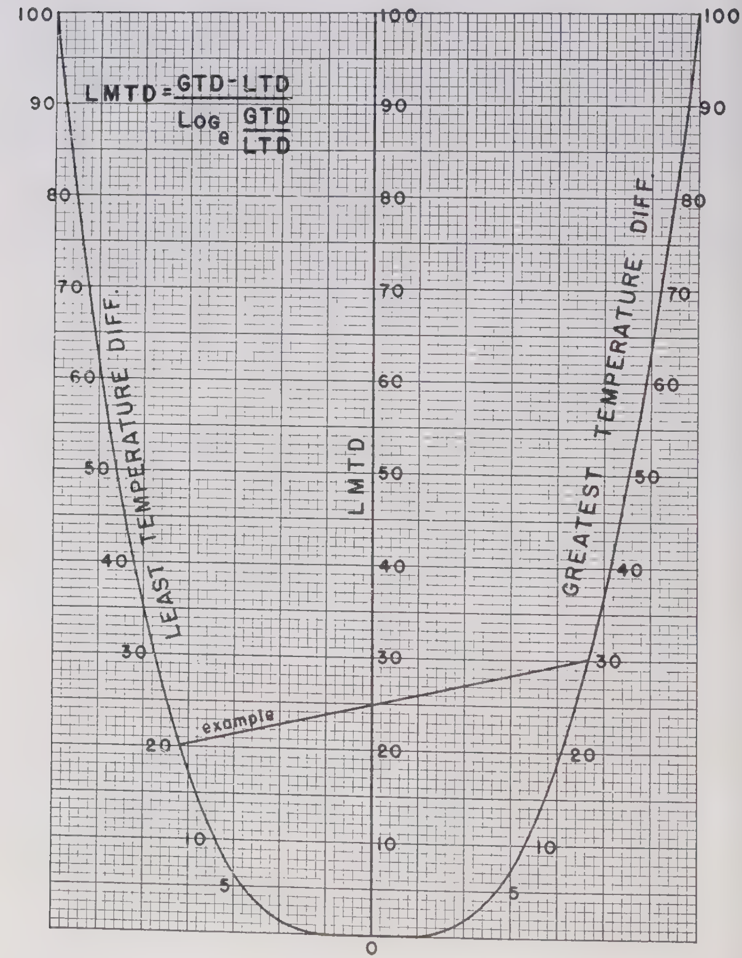
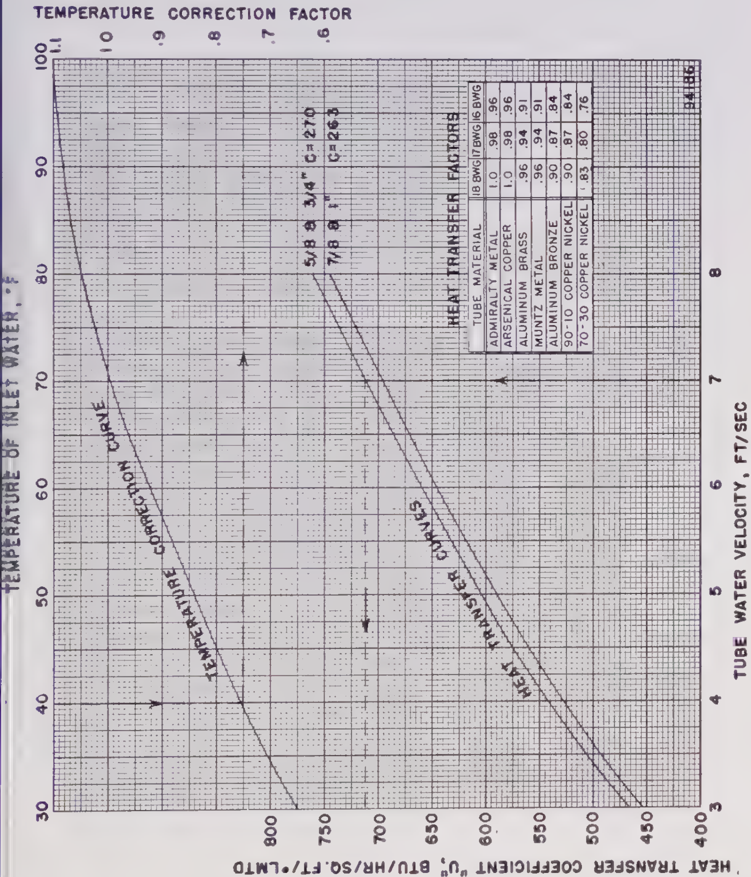
Nomograph for Determining LMTD



Example shows the use of the nomograph to determine LMTD when GTD=30° and LTD =20°. The intersection with the LMTD axis of a line between these points gives a value of LMTD=24.7°.

Nomograph courtesy of Mr. Joseph I. Lacey, Hooker Electrochemical Co.

Heat Transfer Curves for Surface Condensers

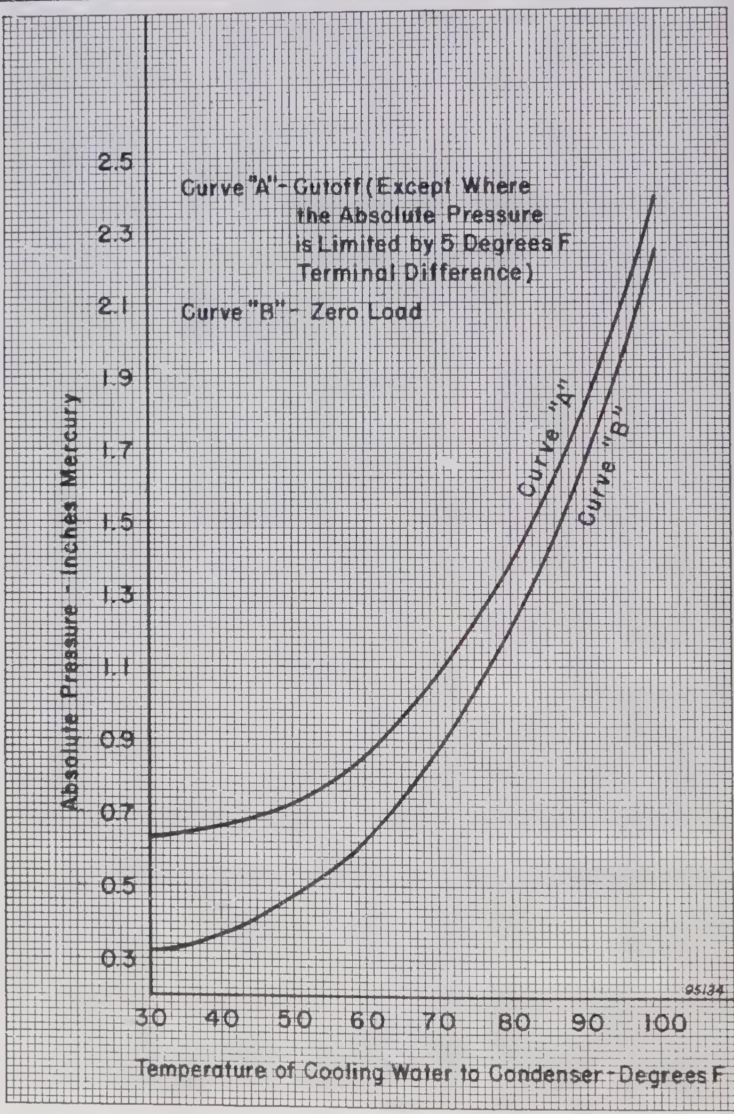


These heat transfer curves are drawn basis $U = C\sqrt{\text{Vel.}}$ for the normal range of water velocities from 3 to 8 fps. max.

Curves are based on No. 18 BWG Admiralty metal tubes with clean oxide-free surfaces and apply only to condensers serving turbines. For engine service, use a factor of .65 to determine heat transfer coefficient.

Curves apply only for normal design or operating conditions involving condenser pressures higher than shown by curve A on the following page.

Reproduced from "Standards for Steam Surface Condensers", Standards of the Heat Exchange Institute.



Above curves show limiting factors on light load operation of surface condensers. Curve A shows the limitation of the air removal equipment and is based on 50% of the air removal capacity as shown on page 174. Curve B shows zero load. Curves for Condenser pressure vs. load are straight lines between values on curves A & B. Reproduced from "Standards for Steam Surface Condensers," Standards of the Heat Exchange Institute.

Water Vapor Refrigeration

Water-Vapor Refrigeration is similar in principle to any of the well-known vapor compression systems except that the water acts as its own refrigerant, thus eliminating the need of any chemical refrigerant. It is particularly suitable for moderate chilled-water temperatures of 40° to 60°F and in some cases as low as 35°F.

The water which is to be cooled enters an evaporator or flash chamber in which there is maintained a very high vacuum (low absolute pressure) corresponding to the desired chilled water temperature. A small portion of the relatively warm entering water immediately boils or flashes into vapor, the latent heat of vaporization being furnished by the remainder of the water, the temperature of which is thereby lowered.

The latent heat of vaporization is approximately 1065 Btu per lb. at .178 lb per sq in absolute (i.e., 50° evaporation temperature) so only about 1% of the entering water is evaporated for each 10° of cooling.

As the vapor is formed, it must be removed and compressed to a lower vacuum (higher absolute pressure) at which its temperature will be sufficiently increased so it can be condensed with cooling water at whatever temperature it is available.

A compressor for this service must have large displacement capacity at very high vacuum. A steam-jet booster, which operates on the well-known ejector principle meets the requirements in every particular.

The unit of refrigerating capacity is called a ton of refrigeration. This equals the amount of heat required to melt a ton (2,000 lb) of ice in 24 hours and corresponds to a heat removal of 12,000 Btu per hr or 200 Btu per min.

The following table shows some of the properties of water vapor applying to its use as a refrigerant. For additional data, see steam tables, pages 140 to 152.

Chilled water temp °F	Suction press in hg abs	Specific vol cu ft/lb	Evaporation rate (theoretical)	
			lb/hr/ton	cfm/ton
35	.204	2947	11.20	550
40	.248	2444	11.23	458
45	.300	2036	11.26	382
50	.363	1703	11.29	321
55	.436	1431	11.31	270
60	.522	1207	11.34	228

Psychrometric Chart
Examples showing use of chart on page 175

CONDITIONS: 95° dry-bulb and 75° wet-bulb.

Relative humidity: At intersection of 75° wet-bulb and 95° dry-bulb the relative humidity is read directly on the curved lines as 40 per cent.

Dew point: At intersection of 75° wet-bulb and 95° dry-bulb lines, the dew point is read directly on horizontal temperature lines as 67°.

Vapor pressure: At intersection of 75° wet-bulb and 95° dry-bulb lines, pass in horizontal direction to left of chart and on scale read the vapor pressure as 0.33 lb per sq in. abs.

Vapor pressure in inches, Hg (at 32°F) = 2.036 × lb/sq in abs.

Vapor pressure in millimeters, Hg (at 32°F) = 51.71 × lb/sq in abs.

Total heat above 0° in mixture per lb of dry air: From where wet-bulb line joins saturation line, follow 75° wet-bulb line upward to its intersection with slanting scale at left of chart read 38.5 Btu per lb of dry air saturated with moisture. The use of this scale to obtain total heat in the mixture at any wet-bulb temperature is a great convenience, as the number of Btu required to heat the mixture and humidify, as well as the refrigeration required to cool and dehumidify the mixture, can be obtained by taking the difference in total heat before and after treatment of the mixture.

Grains of moisture per lb of dry air: From intersection of 95° dry-bulb and 78° wet-bulb temperature lines follow horizontal line to right and read directly 99 grains of moisture per lb.

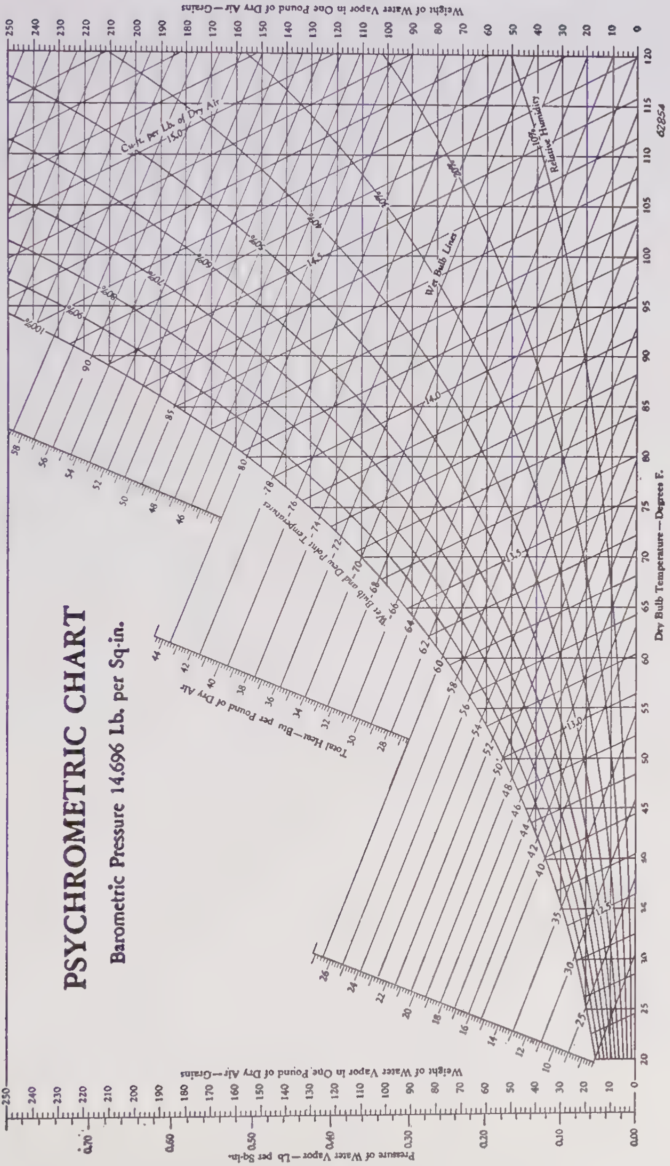
Cu ft of mixture per lb of dry air: At intersection of 75° wet-bulb and 95° dry-bulb lines read directly on diagonal lines 14.29 cu ft per lb, which is the specific volume.

VACUUM PUMP CAPACITIES

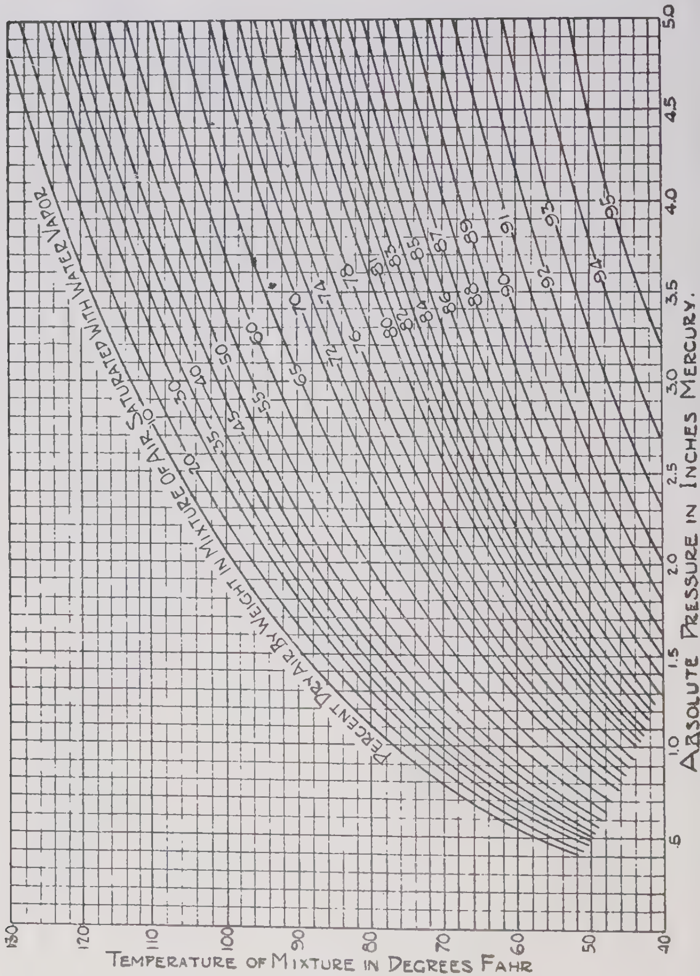
at one inch Hg abs. suction pressure

Maximum Steam Condensed Pounds Per Hour	CFM—70°F Free Dry Air	
	Serving Turbines	Serving Engines
Up to 25,000	3.0	6.0
25,001 to 50,000	4.0	8.0
50,001 to 100,000	5.0	10.0
100,001 to 250,000	7.5	15.0
250,001 to 500,000	10.0	....
500,001 and Up	12.5	....

From "Standards for Steam Surface Condensers", Standards of Heat Exchange Institute.


PSYCHROMETRIC CHART
Barometric Pressure 14.696 Lb. per Sq-in.
Weight of Water Vapor in One Pound of Dry Air—Grains
Dry Bulb Temperature—Degrees F.
Pressure of Water Vapor—Lb per Sq-in.
Total Heat—Btu per Pound of Dry Air
Wet Bulb and Dew Point Temperatures
Wet Bulb Lines
Relative Humidity
Cu-ft per Lb. of Dry Air
62854

Properties of Saturated Air-Vapor Mixtures



Steam Jet Ejectors

For removing air, gases, or vapors from condensers and from vacuum equipment in industrial processes, there is no simpler nor more reliable apparatus than a steam-jet ejector. An ejector is a simplified type of vacuum pump or compressor which has no moving parts such as piston, valves, rotor, etc. It consists essentially of a STEAM NOZZLE which discharges a high velocity jet of steam across a SUCTION CHAMBER where the gas to be evacuated is entrained by the steam and directed into a venturi-shaped DIFFUSOR which converts the velocity energy of the steam into pressure energy of the steam-gas mixture. Several steam-jet ejectors may be used in series or stages.

Condensers of either the direct-contact or surface type are usually used between stages to condense the operating steam from the preceding stage, thereby reducing the load and size of the final ejector stage or stages. Likewise a precooler installed ahead of an ejector reduces the size and steam consumption if the mixture to be handled contains condensable vapors which can be removed at suction pressure and available cooling water temperature. An aftercondenser is frequently used to condense the steam from the final ejector stage although it does not affect the ejector performance.

Steam jet ejectors can be operated in series or staged for absolute pressures down to 1 mm Hg or less. Ejectors can also be operated in parallel for economy or flexibility. Steam jet ejectors are, in general, more suitable for the lower absolute pressures (higher vacuums) than reciprocating pumps, although ejectors can be furnished for any suction and discharge pressure and capacity. Ejectors designed for compressing steam at pressures above atmosphere are termed thermal compressors.

Ejectors are available in suitable materials for handling high temperature or corrosive gases. Ejectors are also suitable for handling wet or dry mixtures, or gases containing sticky or solid material such as chaff, dust, etc.

Ejectors are easy to operate and require very little maintenance. Installation costs are low, and since there are no moving parts they have long life, high sustained efficiency and low maintenance cost.

AVERAGE STEAM CONSUMPTION—LB PER HOUR AT 100 LB GA PRESS

Weight mixture lb/hr	% net dry air by weight	Suction pressure—in hg abs									
		0.5"		1.0"		1.5"	2.0"	3.0"	4.0"		6.0"
		3 Stage	2 Stage	3 Stage	2 Stage	2 Stage	2 Stage	2 Stage	2 Stage	1 Stage	1 Stage
10	100	73	99	59	70	58	50	42	38	58	36
10	70	59	84	47	60	49	42	35	31	63	39
10	40	45	68	33	47	38	32	26	23	68	41
10	10	24	45	16	28	21	17	14	12	74	42

NOTE:—Steam consumption is directly proportional to capacity.

Steam Jet Ejectors

FUNDAMENTAL LAWS OF GASES AND GAS MIXTURES

General

The following brief summary of gas laws gives the formulae most useful in calculating the weights, volumes and partial pressures of gases, or gas mixtures. For all practical purposes it is satisfactory to apply these "ideal gas" laws to all common, true gases ordinarily encountered, including saturated water vapor.

Cfm free air to lb per hour

All performance tables dealing with ejector capacities, are listed in lb per hr. The following formula will be found convenient in changing from cu ft per min free dry air to lb per hr. In working with steam-jet ejectors, the weight of the moisture in the atmosphere can be neglected and free air can therefore be considered as free dry air.

$$\text{Lb per hr} = \text{cu ft per min} \times 60 \times \text{density}$$

The density of air at 14.7 lb per sq in absolute pressure (standard atmospheric pressure) and various temperatures is given in the following table:

Temp. deg fahr	Density lb per cu. ft	Lb/hr for 1 cu ft/min	Temp. deg fahr	Density lb per cu ft	Lb/hr for 1 cu ft/min
30	.08105	4.863	100	.07090	4.254
40	.07943	4.766	110	.06966	4.180
50	.07785	4.671	120	.06845	4.107
60	.07635	4.581	130	.06730	4.038
70	.07493	4.496	140	.06617	3.970
80	.07355	4.413	150	.06510	3.906
90	.07219	4.331			

Specific Volume of a Gas

The following general gas law formula can be used to calculate the specific volume of a gas at any pressure or temperature.

$PV = WRT$, where P is expressed in lb per sq ft.

For convenience in working with absolute pressure in inches of mercury, this formula may be expressed as:

$$PV = \frac{WRT}{70.73} \text{ or } V = \frac{WRT}{70.73P}$$

P = Absolute pressure of gas in inches Hg.
V = Volume of gas in cubic feet
W = Weight of gas in pounds

$$R = \text{Gas Constant} = \frac{1544}{\text{Molecular Weight}}$$

T = Absolute temperature = (460° + °F)

Following are the molecular weights and gas constants "R" for a few of the common gases and vapors:

Steam Jet Ejectors

	Formula	Approx. mol weight	Gas constant R
Hydrogen	H_2	2	772
Carbon monoxide	CO	28	55.1
Oxygen	O_2	32	48.3
Methane	CH_4	16	96.5
Ethylene	C_2H_4	28	55.1
Nitrogen	N_2	28	55.1
Ammonia	NH	17	90.8
Carbon dioxide	CO_2	44	35.1
Steam (water vapor)	H_2O	18	85.8
Sulphur dioxide	SO_2	64	24.1
Air		29	53.3

Partial Pressures

In any mixture of two or more gases, or vapors, each constituent gas exerts its own partial pressure as if it were the only gas present; and the sum of these partial pressures equals the total pressure of the mixture. In other words, each gas or vapor exists at and is governed by its own partial pressure and not, as might be supposed, by the total pressure of the mixture. (Dalton's law).

The mixture usually to be dealt with is made up of a gas and a condensable vapor. If the mixture is saturated with vapor the temperature of the mixture determines the vapor pressure, or the partial pressure of the vapor constituent of the mixture. The partial pressure of the gas is therefore the difference between the total pressure of the mixture and the vapor pressure.

If the mixture is not saturated; i.e., the vapor is superheated, the dew-point temperature of the vapor must first be found from wet and dry-bulb temperature readings, and this dew-point temperature determines the vapor pressure.

TOTAL WEIGHT OF MIXTURE

I—Any Gas and Vapor

The total weight of a saturated mixture made up of two gases one of which is condensable may be obtained from the following form of the general formula:

$$\frac{P_1}{P_v} = \frac{W_1}{W_v} \times \frac{M_v}{M_1} \quad \text{or} \quad W_v = \frac{W_1 \times M_v \times P_v}{M_1 \times P_1}$$

P_1 = Absolute partial pressure of gas
P_v = Absolute partial pressure of vapor
W_1 = Weight of gas, lb
W_v = Weight of vapor, lb
M_1 = Molecular weight of gas
M_v = Molecular weight of vapor

Steam Jet Ejectors

II—Air and Water Vapor

The following, derived from the general formula will be found convenient to use for saturated mixtures of air and water vapor.

$$W_m = W_a + \left(\frac{.6207 \times W_a \times P_v}{P_a}\right)$$

W_m = Weight of mixture in lb
W_a = Weight of air in lb
P_v = Absolute partial vapor pressure
P_a = Absolute partial air pressure

Total Volume of Mixture

In any mixture of two or more gases, or vapors, each constituent gas expands and occupies the entire volume so that the volume of any constituent equals the volume of the mixture.

Because of this relation of volumes and the relation of partial pressures explained above, the general gas law PV = WRT can be used to calculate the volume of any constituent gas at its partial pressure and hence the volume of the mixture.

For example, assume the following saturated air-vapor mixture:
Total pressure — 2.00″ Hg abs
Mixture temperature — 80°F
Weight of air in mixture = 60.18 lb/hr
Partial vapor pressure corresponding to 80°F = 1.032″ Hg abs
Partial air pressure (2.0″ — 1.032″) = .968″ Hg abs
Total Weight of Mixture — 100 lb/hr
Weight of vapor in mixture = 39.82 lb/hr

To calculate the volume of air at its partial pressure, proceed as follows

$$V = \frac{WRT}{70.73 \times P_a}$$

$$\text{Cu ft/hr} = V = \frac{60.18 \times 53.3 \times 540}{70.73 \times .968} = 25{,}300 \text{ or } 421 \text{ cu ft/min}$$

This volume of air is also the volume of the vapor and the total mixture.

As a check, consult the steam tables and find that the specific volume of the vapor at 1.032″ Hg abs is 633.1 cu ft per lb.

The volume of vapor flow is therefore:

Cu ft/hr = 39.82 x 633.1 = 25,210 or 420 cu ft/min

Steam Jet Ejectors

Another check of the vapor volume at its partial pressure may be obtained from the PV = WRT formula

$$V = \frac{W_v RT}{70.73 \times P_v}$$

$$\text{Cu ft/hr} = V = \frac{39.82 \times 85.8 \times 540}{70.73 \times 1.032} = 25{,}275 \text{ or } 421 \text{ cu ft/min}$$

The following tabulation shows the effect of changing the saturation temperature of the air-vapor mixture computed above. If a typical ejector were selected for the 80°F condition, the changes in its net air-handling and volumetric-capacity are clearly indicated.

Mixture temp °F	100	80	60	40
Total press of mixture, " Hg abs	2.0	2.0	2.0	2.0
Partial press of vapor, "Hg abs	1.933	1.032	0.522	0.248
Partial press of air, "Hg abs	0.067	0.968	1.478	1.752
Specific vol vapor, cu ft per lb	350.4	633.1	1207	2444
Percent air in mixture	5.29	60.2	82.0	91.9
Capacity, total, mixture lb per hr	86	100	106	109
Weight air in mixture, lb per hr	4.55	60.2	87.0	100.15
Weight vapor in mixture, lb per hr	81.45	39.8	19.0	8.85
Cu ft/min, vapor (At suction conditions)	475	421	384	360
Cu ft/min, air (At suction conditions)	475	421	384	360
Cu ft/min, mixture (At suction conditions)	475	421	384	360

This table shows that net air capacity is radically influenced by the mixture temperature. It also shows that the total weight of mixture that can be handled is decreased as the saturation temperature is raised although the volumetric capacity increases concurrently. In this respect an air ejector differs from a displacement type of vacuum pump, which tends to maintain constant volumetric capacity. The net air-handling capacity of a mechanical pump is therefore more seriously affected by high saturation temperature.

CHAPTER V

ELECTRICAL DATA

Contents of Chapter V

ELECTRICAL DATA

Notes

Volt (E) is the unit of electric pressure or electromotive force. It is the potential which will produce a current of 1 ampere through a resistance of 1 ohm.

Ampere (I) is the electrical measurement of quantity flowing per sec.

Ohm (R) is the electrical measurement of resistance or electrical friction.

Watt and Kilowatt (kw) are units of electric power.

746 watts = 1hp†

1 kw = 1.341hp†

Kilowatthour (kwhr) is a unit of electrical energy or of work performed

1 kwhr = 2,655,000 ft-lb = 1.341 hp-hr = 3413 Btu†

ELECTRICAL FORMULAE

Required	Direct Current	Alternating current		
		Single-phase	2-phase-4 wire*	3-phase
Amperes when hp is known	$\frac{746(hp)}{(E)\ (eff)}$	$\frac{746(hp)}{(E)\ (eff)\ (pf)}$	$\frac{746(hp)}{2(E)\ (eff)\ (pf)}$	$\frac{746(hp)}{1.73(E)\ (eff)\ (pf)}$
Amperes when kilowatts are known	$\frac{1000(kw)}{E}$	$\frac{1000(kw)}{(E)\ (pf)}$	$\frac{1000(kw)}{2(E)\ (pf)}$	$\frac{1000(kw)}{1.73\ (E)\ (pf)}$
Amperes when kva is known		$\frac{1000(kva)}{E}$	$\frac{1000(kva)}{2(E)}$	$\frac{1000(kva)}{1.73(E)}$
Kilowatts	$\frac{(I)(E)}{1000}$	$\frac{(E)\ (I)\ (pf)}{1000}$	$\frac{2(I)\ (E)\ (pf)}{1000}$	$\frac{1.73(I)\ (E)\ (pf)}{1000}$
Kva		$\frac{(I)\ (E)}{1000}$	$\frac{2(I)\ (E)}{1000}$	$\frac{1.73\ (I)\ (E)}{1000}$
Horsepower Output	$\frac{(I)\ (E)\ (eff)}{746}$	$\frac{(I)\ (E)\ (pf)\ (eff)}{746}$	$\frac{2(I)\ (E)\ (pf)\ (eff)}{746}$	$\frac{1.73\ (I)\ (E)\ (pf)\ (eff)}{746}$

I = amperes

E = volts

eff = efficiency (as a decimal)

hp = horsepower

pf = power factor

kw = kilowatts

kva = kilovolt-amperes

*In 2-phase, 3-wire circuits the current in the common conductor is 1.41 times that in either of the other conductors.

†See note regarding conversions, Page 195.

Usual Service Conditions of Electric Motors.

General-purpose open motors are designed to give successful operation at rated load with temperature rise of 40 deg C under the following service conditions defined as usual—

(a)—An ambient temperature not exceeding 40 deg C.

(b)—A variation in voltage of not more than 10% above or below the nameplate rating.

(c)—A variation in frequency of not more than 5% above or below the nameplate rating.

(d)—A combined variation of voltage and frequency of not more than 10% above or below the nameplate rating, provided the frequency does not exceed the 5% variation.

(e)—An altitude not exceeding 1000 meters (3300 feet). For altitudes above 1000 meters the temperature rise increases approximately 1% for each 100 meters, or 330 feet rise.

(f)—Location or atmospheric conditions such that dust, moisture, or fumes will not seriously interfere with the ventilation of the motor.

Above limits may be exceeded with resultant higher temperature rise, provided maximum observable temperature measured by thermometer for any motor will not exceed 90 deg C.

(g)—Therefore, general-purpose motors may develop a rating 1.15 times the nameplate rating, doing this by exceeding the 40 deg C limit but staying below the 90 deg C maximum.

(h)—Enclosed motors being rated at maximum temperature have no service factor.

(i)—The exceeding of the voltage and frequency limits above will result in increased temperature rise.

Torque

Torque is turning effort caused by a force acting normal to a radius at a set distance from the axis of rotation, and is expressed in pound-feet (lb at radius of 1 ft)

$$\text{Torque (in lb-ft)} = 5250 \times \frac{\text{hp}}{\text{rpm}}$$

The minimum full-voltage starting torque in percent of full-load torque for standard squirrel-cage motors is as follows:

Poles of Motors	Speed	Minimum Starting Torque (% Full Load Torque)
2	3600	150
4	1800	(150 up to 100 hp) (100 for 125 hp and up)
6	1200	(135 up to 100 hp) (100 for 125 hp and up)
8	900	125
10	720	120
12	600	115

Motor Speed

A-C Motors. The synchronous speed of a-c motors is determined by the number of poles and frequency.

$$\text{Synchronous speed} = \frac{120 \times f}{p}$$

where f = frequency in cycles
p = number of poles of the motor

Full-Load Speeds of Synchronous Motors

No of poles	Full-Load Speeds of Synchronous Motors Cycles						
	25	30	40	45	50	60	100
2	1500	1800	2400	2700	3000	3600	....
4	750	900	1200	1350	1500	1800	3000
6	500	600	800	900	1000	1200	2000
8	375	450	600	675	750	900	1500
10	300	360	480	540	600	720	1200
12	250	300	400	450	500	600	1000
14	214.3	257	343	386	428.6	514.2	853.2
16	187.5	225	300	337.5	375	450	750
18	166.6	200	266.6	300	333.3	400	666.4
20	150	180	240	270	300	360	600

Induction motors will have full-load speeds of from 2 to 6% less than the above, average 4% less.

D-C Motors will have standard full-load speeds, when hot, of: 575 850, 1150, 1750, and 3500 rev per min (rpm)

At normal temperature, rated load and voltage the variation above or below the above full-load motor speeds may not exceed 7½% in motors up to 7½ hp at 1150 rpm, and 5% in motors larger than 7½ hp at 1150 rpm.

5

Average Efficiencies for Voltages up to 550 in Three Phase Motors

Rating	Induction Motors			Unity p f syn motors		
	Full Load	¾ Load	½ Load	Full Load	¾ Load	½ Load
1 to 2 hp	81	79	76			
3 to 5 hp	85	84	82			
10 to 25 hp	87.5	87	85			
25 to 50 hp	89	88.5	86.5	90	88.5	85
75-100 hp	91	90	88	92	91	88
150-200 hp	92	91.5	89.5	93	92	89.5
Above 200 hp	93.5	93	91	94.5	93.5	92

The above are averages for 1200 and 1800 rpm motors.

Low speed motors.—Efficiencies will be from 1 to 2% lower—2200 volt motors 100 hp and above have approximately the same efficiency as low voltage motors. On smaller sizes the 2200 volt motors have efficiencies 1 to 2% lower.

Slip ring motors in the smaller sizes will have full load efficiencies of 1 to 3% lower

Power-Factor and Reactive Kva

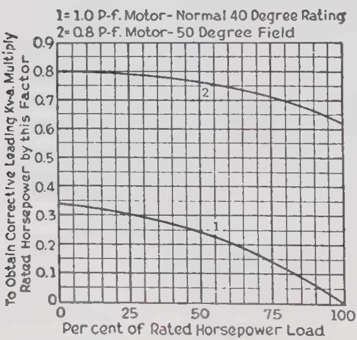


Fig. 1

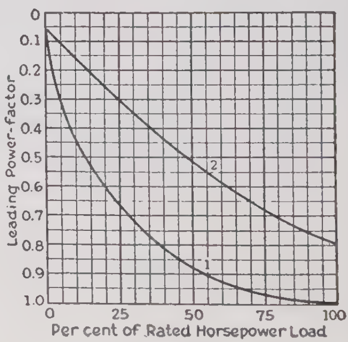


Fig. 2

Fig. 1 of these curves shows a factor which when multiplied by the full-load horsepower rating of the motor, gives the reactive kva delivered by that motor when operating at any load with rated excitation maintained. Fig. 2 shows the corresponding power-factor of the motor.

A more efficient drive may be obtained by purchasing a motor designed for the required load, reactive kva, and power-factor.

Full-Load Motor Current

From National Electrical Code (1947)

THREE-PHASE A.C. MOTORS*†

Induction Type Squirrel Cage and Wound Rotor						Synchronous Type ◉Unity Power Factor				
Hp.	Amperes					Hp.	Amperes			
	110V.	220V.	440V.	550V.	2300V		220V.	440V.	550V.	2300V.
½	4	2	1	8	...	...	...	...	...	...
¾	5.6	2.8	1.4	1.1	...	...	...	...	...	...
1	7	3.5	1.8	1.4	...	...	...	...	...	...
1½	10	5	2.5	2.0	...	...	...	...	...	...
2	13	6.5	3.3	2.6	...	...	...	...	...	...
3	...	9	4.5	4	...	...	...	...	...	...
5	...	15	7.5	6	...	...	...	...	...	...
7½	...	22	11	9	...	...	...	...	...	...
10	...	27	14	11	...	...	...	...	...	...
15	...	40	20	16	...	...	...	...	...	...
20	...	52	26	21	...	...	...	...	...	...
25	...	64	32	26	7	25	54	27	22	5.4
30	...	78	39	31	8.5	30	65	33	26	6.5
40	...	104	52	41	10.5	40	86	43	35	8
50	...	125	63	50	13	50	108	54	44	10
75	...	185	93	74	19	75	161	81	65	15
100	...	246	123	98	25	100	211	106	85	20
125	...	310	155	124	31	125	264	132	106	25
150	...	360	180	144	37	150	...	158	127	30
200	...	480	240	192	49	100	...	210	168	40

Single-Phase A.C. Motors*▣				Direct-Current Motors**			
Hp.	115V.	230V.	440V.	Hp.	115V.	230V.	550V.
⅙	3.2	1.6	...	½	4.6	2.3	...
¼	4.6	2.3	...	1	8.6	4.3	1.8
½	7.4	3.7	...	1½	12.6	6.3	2.6
¾	10.2	5.1	...	2	16.4	8.2	3.4
1	13	6.5	...	3	24	12	5
1½	18.4	9 2	...	5	40	20	8.3
2	24	12	...	7½	58	29	12
3	34	17	...	10	76	38	16
5	56	28	...	15	112	56	23
7½	80	40	21	20	148	74	31
10	100	50	26	25	184	92	38
...	...	...	...	30	220	110	46
...	...	...	...	40	292	146	61
...	...	...	...	50	360	180	75
...	...	...	...	75	536	268	111
...	...	...	...	100	...	355	148
...	...	...	...	125	...	443	148
...	...	...	...	150	...	534	220
...	...	...	...	200	...	712	295

*These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics Motors built for especially low speeds or high torques may require more running current, in which case the nameplate current rating should be used.

†For full-load currents of 208 and 200 volt motors increase the corresponding 220 volt motor full-load current by 6 and 10% respectively.

◉For 90 and 80% P.F. the above figures should be multiplied by 1.1 and 1.25 respectively.

▣For full-load currents of 208 and 200 volt motors increase corresponding 230 volt motor full-load current by 10 and 15% respectively.

**These values for full-load current are average for all speeds.

5

Allowable Carrying Capacities of Copper Wire and Cable

(Regulations of the Natl Board of Fire Underwriters)

No. AWG	Circular Mils	Amperes		Circular Mils	Amperes	
		Rubber Insulation	Varnished Cambric Insulation		Rubber Insulation	Varnished Cambric Insulation
18	1,624	3	4	250,000	250	300
16	2,583	6	8	300,000	275	330
14	4,107	15	18	350,000	300	360
12	6,530	20	25	400,000	325	390
10	10,380	25	30	450,000	362	435
8	16,510	35	40	500,000	400	480
6	26,250	50	60	600,000	450	540
4	41,740	70	85	700,000	500	600
2	66,370	90	110	800,000	550	660
1	83,690	100	120	1,000,000	650	780
0	105,500	125	150	1,250,000	750	900
00	133,100	150	180	1,500,000	850	1020
000	167,800	175	210	1,750,000	950	1140
0000	211,600	225	270	2,000,000	1050	1260

Data on Bare Stranded Copper Wire

(Based on U. S. Bureau of Standards)

Size of Cable Circular Mils	Diam Inches	No of Wires	Diam of Wires Inches	Weight per 1000 ft in lb	Resistance at 25° C (77°F)	
					ohms per 1000 Ft	Ft per ohm at 25°C
250,000	0.576	37	0.0822	772	0.0432	23,150
300,000	0.631	37	0.0900	926	0.0360	27,750
400,000	0.729	37	0.1040	1,240	0.0270	37,050
500,000	0.815	37	0.1162	1,540	0.0216	46,300
750,000	0.999	61	0.1109	2,320	0.0144	69,450
1,000,000	1.153	61	0.1280	3,090	0.0108	92,600
1,250,000	1.289	91	0.1172	3,860	0.00863	115,900
1,500,000	1.413	91	0.1284	4,630	0.00719	139,100
1,750,000	1.527	127	0.1174	5,410	0.00616	162,300
2,000,000	1.632	127	0.1255	6,180	0.00539	185,500

Diameter, Weight and Resistance of Standard Annealed Copper Wire

(Based on U S Bureau of Standards)

No AWG	Diameter Mils	Area Circular Mils	Weight Bare Wire Pounds per 1000 ft	Resistance at 25° C (77° F) Ohms per 1000 ft	Feet per Ohm
0000	460	211,600	640.5	.04998	20,010.
000	410	167,800	507.9	.06302	15,870.
00	365	133,100	402.8	.07947	12,580.
0	325	105,500	319.5	.1002	9,980.
1	289	83,690	253.3	.1264	7,914.
2	258	66,370	200.9	.1593	6,276.
3	229	52,640	159.3	.2009	4,977.
4	204	41,740	126.4	.2533	3,947.
5	182	33,100	100.2	.3195	3,130.
6	162	26,250	79.46	.4028	2,482.
7	144	20,820	63 02	.5080	1,969.
8	128	16,510	49.98	.6405	1,561.
9	114	13,090	39.63	.8077	1,238.
10	102	10,380	31.43	1.018	981.8
11	91	8,234	24.92	1.284	778.7
12	81	6,530	19.77	1.619	617.5
13	72	5,178	15.68	2.042	489.7
14	64	4,107	12.43	2.575	388.3
15	57	3,257	9.858	3.247	308.0
16	51	2,583	7.818	4.094	244.2
17	45	2,048	6.200	5.163	193.7
18	40	1,624	4.917	6.510	153.6
19	36.0	1,288.	3.899	8.210	121.8
20	32.0	1,022.	3.092	10.35	96.60
21	28.5	810.1	2.452	13.05	76.61
22	25.3	642.4	1.945	16.46	60.75
23	22.6	509.5	1.542	20.76	48 18
24	20.1	404.0	1.223	26.17	38.21
25	17.9	320.4	.9699	33.00	30.30
26	15.9	254.1	.7692	41.62	24.03
27	14.2	201.5	.6100	52.48	19.06
28	12.6	159.8	.4837	66.17	15.11
29	11.3	126.7	.3836	83.44	11.98
30	10.0	100.5	.3042	105.2	9.504
31	8.9	79.70	.2413	132.7	7.537
32	8.0	63.21	.1913	167.3	5.977
33	7.1	50.13	.1517	211.0	4.740
34	6.3	39.75	.1203	266.0	3.759
35	5.6	31.52	.09542	335.5	2.981
36	5.0	25.00	.07568	423.0	2.364
37	4.5	19.83	.06001	533.4	1.875
38	4.0	15.72	.04759	672.6	1.487
39	3.5	12.47	.03774	848.1	1.179
40	3.1	9.89	.02993	1,069	0.9350

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CHAPTER VI

MISCELLANEOUS DATA

Contents of Chapter VI

Miscellaneous Data

General Notes

In the British "gravitational" system of units, commonly in use by engineers in the USA, the proper meaning of certain fundamental terms should be kept in mind.

The pound (lb) is the unit applying to force or weight and also to mass, but with a different meaning. It is therefore ambiguous, and confusion in its use may result. **Force** is a "quantity" (of something rather undefinable, a primary cause known only by its effects) which will change the velocity of—accelerate or decelerate—a particle of matter. **Weight** of a body means the force required to support it against the action of gravity (in that locality). **Mass** is defined by the relation; Force = mass × acceleration = weight × acceleration of gravity. To avoid confusion we should really speak of "lb force" and "lb mass".

The foot (ft) is the "arbitrarily selected" unit of length.

The foot-pound (ft-lb) is the unit of work, or of mechanical energy which is the capacity to do work. 1 ft-lb is the work performed by a force of 1 lb acting through a distance of 1 ft; or the work required to lift a weight of 1 lb vertically by 1 ft; or the potential energy of the weight after being raised, in reference to its former level. (Standard conversions of ft-lb to other units are based on the acceleration of gravity at sea level, 45° lat),

The horsepower (hp) is a unit for measuring power, or work performed in unit time. It is a **rate** of doing work or expending mechanical energy

1 hp = 550 ft-lb per sec = 33,000 ft-lb per min = .7067 Btu per sec.

1 hp = .7457kw

The horsepower-hour (hp-hr) is a unit of work; so is the **kilowatt-hour** (kwhr). The time consumed may be anything, say a fraction of a second or a million years, depending on the rate at which the work is performed. It is one hour only if the rate of work is 1 hp or 1kw.

1 hp-hr = 1,980,000 ft-lb = 2545 Btu = .7457 kwhr.

1 kwhr = 1.341 hp-hr = 3413 Btu = 2,655,000 ft-lb

Torque is turning effort caused by a force acting normal to a radius at a set distance from the axis of rotation, and is expressed in pound-feet (lb at a radius of 1 ft).

$$\text{Torque (in lb-ft)} = \text{force (in lb)} \times \text{lever arm (in ft)} = \frac{5250\,(\text{hp})}{\text{rpm}}$$

Conversions . . . Equations involving units of measure are of two types: (1) equations of equivalent physical quantities, such as 12 in. = 1ft; and (2) equations of equivalent numerical value, such as (no of in.) = 12 × (no. of ft). In making conversions or in substituting terms in a formula the second type is usually more convenient.

Metric Conversion Table

To convert from	To	Multiply by	To convert from	To	Multiply by
Length			**Length**		
mm	inches	.03937	inches	mm	25.40
cm	inches	.3937	inches	cm	2.540
meters	inches	39.37	inches	meters	.0254
meters	feet	3.281	feet	meters	.3048
meters	yards	1.0936	feet	km	.0003048
km	feet	3280.8	yards	meters	.9144
km	yards	1093.6	yards	km	.0009144
km	miles	.6214	miles	km	1.609
Area			**Area**		
sq mm	sq inches	.00155	sq inches	sq mm	645.2
sq cm	sq inches	.155	sq inches	sq cm	6.452
sq meters	sq feet	10.764	sq feet	sq meters	.09290
sq meters	sq yards	1.196	sq yards	sq meters	.8361
sq km	sq miles	.3861	sq miles	sq km	2.590
hectares	acres	2.471	acres	hectares	.4047
Volume			**Volume**		
cu cm	cu inches	.06102	cu inches	cu cm	16.387
cu cm	fl ounces	.03381	cu inches	liters	.01639
cu meters	cu feet	35.314	cu feet	cu meters	.02832
cu meters	cu yards	1.308	cu feet	liters	28.317
cu meters	US gal	264.2	cu yards	cu meters	.7646
liters	cu inches	61.023	fl ounces	cu cm	29.57
liters	cu feet	.03531	US gal	cu meters	.003785
liters	US gal	.2642	US gal	liters	3.785
Weight			**Weight**		
grams	grains	15.432	grains	grams	.0648
grams	ounces†	.0353	ounces†	grams	28.350
kg	ounces†	35.27	ounces†	kg	.02835
kg	pounds†	2.2046	pounds†	kg	.4536
kg	US tons	.001102	pounds†	tonnes	.000454
kg	long tons	.000984	US tons	kg	907.2
tonnes	pounds†	2204.6	US tons	tonnes	.9072
tonnes	US tons	1.1023	long tons	kg	1016
tonnes	long tons	.9842	long tons	tonnes	1.0160

†avoirdupois pounds and ounces.

Metric Conversion Table

To convert from	To	Multiply by	To convert from	To	Multiply by
Unit weight			**Unit weight**		
gr/sq cm	lb/sq in	.01422	lb/ft	kg/m	1.4881
gr/cu cm	lb/cu in	.0361	lb/sq in	gr/sq cm	70.31
kg/sq cm	lb/sq in	14.22	lb/sq in	kg/sq cm	.07031
kg/cu m	lb/cu ft	.0624	lb/cu in	gr/cu cm	27.68
kg/m	lb/ft	.6720	lb/cu ft	kg/cu m	16.018
Unit volume			**Unit volume**		
liters/min	US gpm	.2642	US gpm	liters/min	3.785
liters/min	cfm	.03531	US gpm	liters/hr	227.1
liters/hr	US gpm	.0044	US gpm	cu m/hr	.2271
cu m/min	cfm	35.314	cfm	liters/min	28.317
cu m/hr	cfm	.5886	cfm	cu m/min	.02832
cu m/hr	US gpm	4.4028	cfm	cu m/hr	1.6992
Power			**Power**		
watts	ft-lb/sec	.7376	ft-lb/sec	watts	1.356
watts	hp	.00134	hp	watts	745.7
kw	hp	1.3410	hp	kw	.7457
cheval-vap	hp	.9863	hp	cheval-vap	1.0139
Heat			**Heat**		
gr-cal	Btu	.003969	Btu	gr-cal	252
kg-cal	Btu	3.9693	Btu	kg-cal	.252
kg-cal/kg	Btu/lb	1.800	Btu/lb	kg-cal/kg	.5556
gr-cal/sq cm	Btu/sq ft	3.687	Btu/sq ft	gr-cal/sq cm	.2713
kg-cal/cu m	But/cu ft	.1124	Btu/cu ft	kg-cal/cu m	8.899
Work or energy			**Work or energy**		
joule	ft-lb	.7376	ft-lb	joule	1.356
meter-kg	ft-lb	7.2330	ft-lb	meter-kg	.1383
gr-cal	ft-lb	3.087	ft-lb	gr-cal	.3239
kg-cal	ft-lb	3087	ft-lb	kg-cal	.000324
hp-hr	ft-lb	1,980,000	ft-lb	hp-hr	5.05×10^{-7}
kwhr	ft-lb	2,655,000	ft-lb	kwhr	3.766×10^{-7}
Btu	ft-lb	778.0	ft-lb	Btu	.001285

English Conversion Table

To Convert From	To	Multiply By	To Convert From	To	Multiply By
Length			**Volume**		
inches	feet	.0833	cu inches	cu feet	.0005787
inches	yards	.0278	cu inches	cu yards	.00002143
feet	inches	12	cu inches	US gal	.004329
feet	yards	.3333	cu feet	cu inches	1728
feet	miles	.0001894	cu feet	cu yards	.03704
yards	feet	3	cu feet	US gal	7.481
yards	miles	.0005682	cu yards	cu inches	46, 656
			cu yards	cu feet	27
Area			**Weight (Avoirdupois)**		
sq inches	sq feet	.00694	grains	ounces	.002286
sq inches	sq yards	.000772	ounces	grains	437.5
sq feet	sq inches	144	ounces	pounds	.0625
sq feet	sq yards	.11111	pounds	ounces	16
sq yards	sq inches	1296	pounds	US tons	.0005
sq yards	sq feet	9	pounds	long tons	.000446
sq yards	acres	.000207	US tons	pounds	2000
acres	sq feet	43,560	long tons	pounds	2240
acres	sq yards	4840			

Circumference of Circle $= 3.1416 \times$ dia $= 6.2832 \times$ radius

Area of Circle $= .7854 \times (\text{dia})^2 = 3.1416 \times (\text{radius})^2$

Area of Sphere $= 3.1416 \times (\text{dia})^2$

Volume of Sphere $= .5236 \times (\text{dia})^3$

1 lb per sq in is equivalent to .06804 atmospheres.

Conversion Table—Cu ft/sec to gpm to gal/24 hr

Cu. Ft. per sec.	to Gallons per minute	to Gallons per 24 hrs.	Gallons per 24 hrs.	to Gallons per minute	to Cu. Ft. per sec.
0.2	90	129,254	100,000	69	0.15
0.4	180	258,508	125,000	87	0.19
0.6	269	387,763	200,000	139	0.31
0.8	359	517,017	400,000	278	0.62
1.0	449	646,272	500,000	347	0.77
1.2	539	775,526	600,000	417	0.93
1.4	628	904,780	700,000	486	1.08
1.6	718	1.034,036	800,000	556	1.24
1.8	808	1,163,290	900,000	625	1.39
2.0	898	1,292,544	1,000,000	694	1.55
2.2	987	1,421,798	2,000,000	1,389	3.09
2.4	1,077	1,551,053	3,000,000	2,083	4.64
2.6	1.167	1,680,307	4,000,000	2,778	6.19
2.8	1,257	1,809,562	5,000,000	3,472	7.74
3.0	1,346	1,938,816	6,000,000	4,167	9.28
3.2	1,436	2,068,070	7,000,000	4,861	10.83
3.4	1,526	2,197,325	8,000,000	5,556	12.38
3.6	1,616	2,326,579	9,000,000	6,250	13.92
3.8	1,705	2,455,834	10,000,000	6,944	15.47
4.0	1,795	2,585,088	12,000,000	8,333	18.56
4.2	1,885	2,714,342	12,500,000	8,680	19.34
4.4	1,975	2,843,597	14,000,000	9,722	21.65
4.6	2,068	2,972,851	15,000,000	10,417	23.20
4.8	2,154	3,102,106	16,000,000	11,111	24.75
5.0	2,244	3,231,360	18,000,000	12,500	26.85
10.0	4,488	6,462,720	20,000,000	13,889	30.94
20.0	8,987	12,925,440	25,000,000	17,361	38.68
30.0	13,464	19,388,160	30,000,000	20,833	46.41
40.0	17,952	25,850,880	40,000,000	27,778	61.88
50.0	22,440	32,313,600	50,000,000	34,722	77.35
60.0	26,928	38,776,320	60,000,000	41,667	92.82
70.0	31,416	45,239,040	70,000,000	48,611	108.29
75.0	33,660	48,470,000	75,000,000	52,083	116.04
80.0	35,904	51,701,760	80,000,000	55,556	123.76
90.0	40,392	58,164,480	90,000,000	62,500	139.23
100.0	44,880	64,627,200	100,000,000	69,444	154.72
101.0	45,329	65,273,472	125,000,000	86,805	193.40
102.0	45,778	65,919,744	150,000,000	104,167	232.08
103.0	46,226	66,566,016	175,000,000	121,528	270.76
104.0	46,675	67,212,288	200,000,000	138,889	309.44
105.0	47,124	67,858,560	225,000,000	156,250	348.12
106.0	47,572	68,504,832	250,000,000	173,611	386.80
107.0	48,022	69,151,104	300,000,000	208,333	464.16
108.0	48,470	69,797,376	400,000,000	277,778	618.88
109.0	48,919	70,443,648	500,000,000	347,220	773.60
110.0	49,368	71,089,920	600,000,000	416,664	928.32
120.0	53,856	77,552,640	700,000,000	486,108	1,083.04
125.0	56,100	80,784,000	750,000,000	520,328	1,160.40
130.0	58,344	84,015,360	800,000,000	555,552	1,237.76
140.0	62,832	90,478,080	900,000,000	624,996	1,392.48
150.0	67,320	96,940,800	1,000,000,000	694,440	1,547.20

NOTE:—gpm and gal per 24 hr given to the nearest whole number.
The value 7.48 gallons equals 1 cu ft is used in calculating above table.

Logarithms to base 10

Number	0	1	2	3	4	5	6	7	8	9	Proportional Parts								
											1	2	3	4	5	6	7	8	9
1.0	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
1.1	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
1.2	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
1.3	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
1.4	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
1.5	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
1.6	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
1.7	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
1.8	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
1.9	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
2.0	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
2.1	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
2.2	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
2.3	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
2.4	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
2.5	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
2.6	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
2.7	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
2.8	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
2.9	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
3.0	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
3.1	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
3.2	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
3.3	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
3.4	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
3.5	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
3.6	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
3.7	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
3.8	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
3.9	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
4.0	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
4.1	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
4.2	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
4.3	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
4.4	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
4.5	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
4.6	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
4.7	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
4.8	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
4.9	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
5.0	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
5.1	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5		7	8
5.2	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5		7	7
5.3	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5		6	7
5.4	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5		6	7

$\text{Log } \pi = 0.49715.$

$\text{Log}_e = 2.3025851 \times \text{Log}_{10}$

Logarithms to base 10
(Continued)

Number	0	1	2	3	4	5	6	7	8	9	Proportional Parts 1	2	3	4	5	6	7	8	9
5.5	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
5.6	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
5.7	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
5.8	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
5.9	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
6.0	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
6.1	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
6.2	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
6.3	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
6.4	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
6.5	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
6.6	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
6.7	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
6.8	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
6.9	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
7.0	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
7.1	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
7.2	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
7.3	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
7.4	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
7.5	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
7.6	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
7.7	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
7.8	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
7.9	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
8.0	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
8.1	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
8.2	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
8.3	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
8.4	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
8.5	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
8.6	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
8.7	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
8.8	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
8.9	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
9.0	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
9.1	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
9.2	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
9.3	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
9.4	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
9.5	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
9.6	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
9.7	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
9.8	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
9.9	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

Decimal and Millimeter Equivalents

of 4ths, 8ths, 16ths, 32nds and 64ths

Fraction	Decimal Equivalent	Millimeter Equivalents
4ths and 8ths		
1/8	.125	3.175
1/4	.250	6.350
3/8	.375	9.525
1/2	.500	12.700
5/8	.625	15.875
3/4	.750	19.050
7/8	.875	22.225
16ths		
1/16	.0625	1.588
3/16	.1875	4.763
5/16	.3125	7.938
7/16	.4375	11.113
9/16	.5625	14.288
11/16	.6875	17.463
13/16	.8125	20.638
15/16	.9375	23.813
32nds		
1/32	.03125	.794
3/32	.09375	2.381
5/32	.15625	3.969
7/32	.21875	5.556
9/32	.28125	7.144
11/32	.34375	8.731
13/32	.40625	10.319
15/32	.46875	11.906
17/32	.53125	13.494
19/32	59375	15.081
21/32	.65625	16.669
23/32	.71875	18.256
25/32	.78125	19.844
27/32	.84375	21.431
29/32	.90625	23.019
31/32	.96875	24.606

Fraction	Decimal Equivalent	Millimeter Equivalents
64ths		
1/64	.015625	.397
3/64	.046875	1.191
5/64	.078125	1.984
7/64	.109375	2.778
9/64	.140625	3.572
11/64	.171875	4.366
13/64	.203125	5.159
15/64	.234375	5.953
17/64	.265625	6.747
19/64	.296875	7.541
21/64	.328125	8.334
23/64	.359375	9.128
25/64	.390625	9.922
27/64	.421875	10.716
29/64	.453125	11.509
31/64	.484375	12.303
33/64	.515625	13.097
35/64	.546875	13.891
37/64	.578125	14.684
39/64	.609375	15.478
41/64	.640625	16.272
43/64	.671875	17.066
45/64	.703125	17.859
47/64	.734375	18.653
49/64	.765625	19.447
51/64	.796875	20.241
53/64	.828125	21.034
55/64	.859375	21.828
57/64	.890625	22.622
59/64	.921875	23.416
61/64	.953125	24.209
63/64	.984375	25.003

Areas of Circles

Diameters in Inches and Areas in Square Inches

Dia	Area	Dia	Area	Dia	Area	Dia	Area	Dia	Area
⅛	.012272	½	44.1787	⅞	173.782	½	471.436	¼	1209.958
¼	.049087	⅝	45.6636	15	176.715	¾	481.107	½	1225.42
⅜	.110447	¾	47.1731	⅛	179.673	25	490.875	¾	1240.981
½	.19635	⅞	48.7071	¼	182.655	¼	500.742	40	1256.64
⅝	.306796	8	50.2656	⅜	185 661	½	510.706	¼	1272.397
¾	.441787	⅛	51.8487	½	188 692	¾	520.769	½	1288.252
⅞	.601322	¼	53.4563	⅝	191 748	26	530.93	¾	1304.206
1	.7854	⅜	55.0884	¾	194.828	¼	541.19	41	1320.257
⅛	.99402	½	56.7451	⅞	197.933	½	551.547	¼	1336.407
¼	1.2272	⅝	58.4264	16	201.062	¾	562.003	½	1352.655
⅜	1.4849	¾	60.1322	⅛	204.216	27	572.557	¾	1369.001
½	1.7671	⅞	61.8625	¼	207 395	¼	583.209	42	1385.45
⅝	2.0739	9	63.6174	⅜	210.598	½	593 959	¼	1401.99
¾	2 4053	⅛	65.3968	½	213.825	¾	604 807	½	1418.63
⅞	2 7612	¼	67.2008	⅝	217 077	28	615 754	¾	1435.37
2	3.1416	⅜	69 0293	¾	220 354	¼	626.798	43	1452.2
⅛	3.5466	½	70 8823	⅞	223.655	½	637.941	½	1469.14
¼	3 9761	⅝	72 7599	17	226 981	¾	649.182	½	1486.17
⅜	4 4301	¾	74 6621	⅛	230 331	29	660.521	¾	1503.3
½	4.9087	⅞	76 5888	¼	233.706	¼	671.959	44	1520.53
⅝	5 4119	10	78.54	⅜	237 105	½	683.494	½	1555.29
¾	5 9396	⅛	80 5158	½	240 529	¾	695.128	45	1590.43
⅞	6 4918	¼	82 5161	⅝	243 977	30	706.86	½	1625.97
3	7.0686	⅜	84 5409	¾	247 45	¼	718.69	46	1661.91
⅛	7.6699	½	86 5903	⅞	250 948	½	730 618	½	1698.23
¼	8.2958	⅝	88 6643	18	254 47	¾	742.645	47	1734.95
⅜	8.9462	¾	90 7628	⅛	258 016	31	754.769	½	1772.06
½	9.6211	⅞	92 8858	¼	261 587	¼	766.992	48	1809.56
⅝	10 3206	11	95 0334	⅜	265 183	½	779.313	½	1847.46
¾	11 0447	⅛	97 2055	½	268.803	¾	791.732	49	1885.75
⅞	11 7933	¼	99 4022	⅝	272 448	32	804 25	½	1924.43
4	12 5664	⅜	101 6234	¾	276 117	¼	816 865	50	1963.5
⅛	13 3641	½	103 8691	⅞	279 811	½	829 579	½	2002.97
¼	14 1863	⅝	106 1394	19	283.529	¾	842 391	51	2042.83
⅜	15 033	¾	108 4343	⅛	287 272	33	855.301	½	2083.08
½	15.9043	⅞	110.7537	¼	291 04	¼	868 309	52	2123.72
⅝	16 8002	12	113 098	⅜	294 832	½	881.415	½	2164.76
¾	17.7206	⅛	115 466	½	298 648	¾	894 62	53	2206.19
⅞	18 6655	¼	117 859	⅝	302 489	34	907 922	½	2248.01
5	19 635	⅜	120.277	¾	306 355	¼	921 323	54	2290.1
⅛	20 629	½	122 719	⅞	310 245	½	934.822	½	2332.9
¼	21.6476	⅝	125 185	20	314 16	¾	948 42	55	2376.4
⅜	22.6907	¾	127.677	¼	322.063	35	962 115	56	2463.4
½	23.7583	⅞	130.192	½	330 064	¼	975.909	57	2551.8
⅝	24.8505	13	132 733	¾	338.164	½	989.9	58	2641
¾	25.9673	⅛	135 297	21	346 361	¾	1003.79	59	2734.
⅞	27.1086	¼	137.887	¼	354 657	36	1017 878	60	2834.
6	28.2744	⅜	140.501	½	363.051	¼	1032 065	61	2921
⅛	29.4648	½	143.139	¾	371.543	½	1046.349	62	3019
¼	30.6797	⅝	145 802	22	380.134	¾	1060.732	63	3117
⅜	31.9191	¾	148.49	¼	388 822	37	1075.213	64	3217
½	33.1831	⅞	151.202	½	397.609	¼	1089.792	65	3318
⅝	34.4717	14	153.938	¾	406.494	½	1104.469	66	3421
¾	35.7848	⅛	156.7	23	415.477	¾	1119.244	67	3527
⅞	37.1224	¼	159.485	¼	424.558	38	1134.118	68	3632
7	38.4846	⅜	162.296	½	433.737	¼	1149.089	69	3739
⅛	39.8713	½	165.13	¾	443 015	½	1164.159	70	3849
¼	41.2826	⅝	167.99	24	452 39	¾	1179 327	71	3960
⅜	42.7184	¾	170.874	¼	461.864	39	1194.593	72	4071

6

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales

$F^\circ = \frac{9}{5} C^\circ + 32^\circ$ $\qquad$ $C^\circ = \frac{5}{9} (F^\circ - 32^\circ)$

Fahrenheit deg	Centigrade deg	Fahrenheit deg	Centigrade deg	Fahrenheit deg	Centigrade deg	Fahrenheit deg	Centigrade deg
—459.4	—273	—21.	—29.4	17.6	—8.	56.	13.3
—436.	—260.	—20.2	—29.	18.	—7.8	57.	13.9
—418.	—250.	—20.	—28.9	19.	—7.2	57.2	14.
—400.	—240.	—19.	—28.3	19.4	—7.	58.	14.4
—382.	—230.	—18.4	—28.	20.	—6.7	59.	15.
—364.	—220.	—18.	—27.8	21.	—6.1	60.	15.6
—346.	—210.	—17.	—27.2	21.2	—6.	60.8	16.
—328.	—200.	—16.6	—27.	22.	—5.6	61.	16.1
—310.	—190.	—16.	—26.7	23.	—5.	62.	16.7
—292.	—180.	—15.	—26.1	24.	—4.4	62.6	17.
—274.	—170.	—14.8	—26.	24.8	—4.	63.	17.2
—256.	—160.	—14.	—25.6	25.	—3.9	64.	17.8
—238.	—150.	—13.	—25.	26.	—3.3	64.4	18.
—220.	—140	—12.	—24.4	26.6	—3.	65.	18.3
—202.	—130.	—11.2	—24.	27.	—2.8	66.	18.9
—184.	—120.	—11.	—23.9	28.	—2.2	66.2	19.
—166.	—110.	—10.	—23.3	28.4	—2.	67.	19.4
—148.	—100.	— 9.4	—23.	29.	—1.7	68.	20.
—139.	— 95.	— 9.	—22.8	30.	—1.1	69.	20.6
—130.	— 90.	— 8.	—22.2	30.2	—1.	69.8	21.
—121.	— 85.	— 7.6	—22.	31.	—0.6	70.	21.1
—112.	— 80.	— 7.	—21.7	32.	0.	71.	21.7
—103.	— 75	— 6.	—21.1	33.	+0.6	71.6	22.
— 94.	— 70.	— 5.8	—21.	33.8	1.	72.	22.2
— 85.	— 65.	— 5.	—20.6	34.	1.1	73.	22.8
— 76.	— 60.	— 4.	—20.	35.	1.7	73.4	23.
— 67.	— 55.	— 3.	—19.4	35.6	2.	74.	23.3
— 58.	— 50.	— 2.2	—19.	36.	2.2	75.	23.9
— 49.	— 45.	— 2.	—18.9	37.	2.8	75.2	24.
— 40.	— 40.	— 1.	—18.3	37.4	3.	76.	24.4
— 39.	— 39.4	— 0.4	—18.	38.	3.3	77.	25.
— 38.2	— 39.	0.	—17.8	39.	3.9	78.	25.6
— 38.	— 38.9	+ 1.	—17.2	39.2	4.	78.8	26.
— 37.	— 38.3	1.4	—17.	40.	4.4	79.	26.1
— 36.4	— 38.	2.	—16.7	41.	5.	80.	26.7
— 36.	— 37.8	3.	—16.1	42.	5.6	80.6	27.
— 35.	— 37.2	3.2	—16.	42.8	6.	81.	27.2
— 34.6	— 37.	4.	—15.6	43.	6.1	82.	27.8
— 34.	— 36.7	5.	—15.	44.	6.7	82.4	28.
— 33.	— 36.1	6.	—14.4	44.6	7.	83.	28.3
— 32.8	— 36.	6.8	—14.	45.	7.2	84.	28.9
— 32.	— 35.6	7.	—13.9	46.	7.8	84.2	29.
— 31.	— 35.	8.	—13.3	46.4	8.	85.	29.4
— 30.	— 34.4	8.6	—13.	47.	8.3	86.	30.
— 29.2	— 34.	9.	—12.8	48.	8.9	87.	30.6
— 29.	— 33.9	10.	—12.2	48.2	9.	87.8	31.
— 28.	— 33.3	10.4	—12.	49.	9.4	88.	31.1
— 27.4	— 33.	11.	—11.7	50.	10.	89.	31.7
— 27.	— 32.8	12.	—11.1	51.	10.6	89.6	32.
— 26.	— 32.2	12.2	—11.	51.8	11.	90.	32.2
— 25.6	— 32.	13.	—10.6	52.	11.1	91.	32.8
— 25.	— 31.9	14.	—10.	53.	11.7	91.4	33.
— 24.	— 31.7	15.	— 9.4	53.6	12.	92.	33.3
— 23.8	— 31.1	15.8	— 9.	54.	12.2	93.	33.9
— 23.	— 30.	16.	— 8.9	55.	12.8	93.2	34.
— 22.	— 30.	17.	— 8.3	55.4	13.	94.	34.4

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales

(Continued)

Fahrenheit deg	Centigrade deg	Fahrenheit deg	Centigrade deg	Fahrenheit deg	Centigrade deg	Fahrenheit deg	Centigrade deg
95.	35.	134.	56.7	172.4	78.	211.	99.4
96.	35.6	134.6	57.	173.	78.3	212.	100.
96.8	36.	135.	57.2	174.	78.9	213.	100.6
97.	36.1	136.	57.8	174.2	79.	213.8	101.
98.	36.7	136.4	58.	175.	79.4	214.	101.1
98.6	37.	137.	58.3	176.	80.	215.	101.7
99.	37.2	138.	58.9	177.	80.6	215.6	102.
100.	37.8	138.2	59.	177.8	81.	216.	102.2
100.4	38.	139.	59.4	178.	81.1	217.	102.8
101.	38.3	140.	60.	179.	81.7	217.4	103.
102.	38.9	141.	60.6	179.6	82.	218.	103.3
102.2	39.	141.8	61.	180.	82.2	219.	103.9
103.	39.4	142.	61.1	181.	82.8	219.2	104.
104.	40.	143.	61.7	181.4	83.	220.	104.4
105.	40.6	143.6	62.	182.	83.3	221.	105.
105.8	41.	144.	62.2	183.	83.9	222.	105.6
106.	41.1	145.	62.8	183.2	84.	222.8	106.
107.	41.7	145.4	63.	184.	84.4	223.	106.1
107.6	42.	146.	63.3	185.	85.	224.	106.7
108.	42.2	147.	63.9	186.	85.6	224.6	107.
109.	42.8	147.2	64.	186.8	86.	225.	107.2
109.4	43.	148.	64.4	187.	86.1	226.	107.8
110.	43.3	149.	65.	188.	86.7	226.4	108.
111.	43.9	150.	65.6	188.6	87.	227.	108.3
111.2	44.	150.8	66.	189.	87.2	228.	108.9
112.	44.4	151.	66.1	190.	87.8	228.2	109.
113.	45.	152.	66.7	190.4	88.	229.	109.4
114.	45.6	152.6	67.	191.	88.3	230.	110.
114.8	46.	153.	67.2	192.	88.9	231.	110.6
115.	46.1	154.	67.8	192.2	89.	231.8	111.
116.	46.7	154.4	68.	193.	89.4	232.	111.1
116.6	47.	155.	68.3	194.	90.	233.	111.7
117.	47.2	156.	68.9	195.	90.6	233.6	112.
118.	47.8	156.2	69.	195.8	91.	234.	112.3
118.4	48.	157.	69.4	196.	91.1	235.	112.8
119.	48.3	158.	70.	197.	91.7	235.4	113.
120.	48.9	159.	70.6	197.6	92.	236.	113.3
120.2	49.	159.8	71.	198.	92.2	237.	113.9
121.	49.4	160.	71.1	199.	92.8	237.2	114.
122.	50.	161.	71.7	199.4	93.	238.	114.4
123.	50.6	161.6	72.	200.	93.3	239.	115.
123.8	51.	162.	72.2	201.	93.9	240.	115.6
124.	51.1	163.	72.8	201.2	94.	240.8	116.
125.	51.7	163.4	73.	202.	94.4	241.	116.1
125.6	52.	164.	73.3	203.	95.	242.	116.7
126.	52.2	165.	73.9	204.	95.6	242.6	117.
127.	52.8	165.2	74.	204.8	96.	243.	117.2
127.4	53.	166.	74.4	205.	96.1	244.	117.8
128.	53.3	167.	75.	206.	96.7	244.4	118.
129.	53.9	168.	75.6	206.6	97.	245.	118.3
129.2	54.	168.8	76.	207.	97.2	246.	118.9
130.	54.4	169.	76.1	208.	97.8	246.2	119.
131.	55.	170.	76.7	208.4	98.	247.	119.4
132.	55.6	170.6	77.	209.	98.3	248.	120.
132.8	56.	171.	77.2	210.	98.9	249.	120.6
133.	56.1	172.	77.8	210.2	99.	249.8	121.

Correction for Relative Expansion of Mercury and Brass Scale to 32°F Standard

TABLE 1

Temp Hg Col °F	Observed reading of the barometer, in inches												
	25	25.5	26	26.5	27	27.5	28	28.5	29	29.5	30	30.5	31.0
	Correction to be subtracted from observed reading												
40	.026	.026	.027	.027	.028	.028	.029	.029	.030	.030	.031	.031	.032
42	.030	.031	.032	.032	.033	.033	.034	.035	.035	.036	.036	.037	.038
44	.035	.036	.036	.037	.038	.038	.039	.040	.040	.041	.041	.042	.043
46	.039	.040	.041	.042	.043	.043	.044	.045	.046	.046	.047	.048	.049
48	.044	.045	.046	.047	.047	.048	.049	.050	.051	.052	.053	.054	.054
50	.048	.049	.050	.051	.052	.053	.054	.055	.056	.057	.058	.059	.060
52	.053	.054	.055	.056	.057	.058	.059	.060	.061	.062	.064	.065	.066
54	.057	.059	.060	.061	.062	.063	.064	.066	.067	.068	.069	.070	.071
56	.062	.063	.064	.066	.067	.068	.069	.071	.072	.073	.074	.076	.077
58	.066	.068	.069	.070	.072	.073	.074	.076	.077	.078	.080	.081	.082
60	.071	.072	.074	.075	.077	.078	.080	.081	.082	.084	.085	.087	.088
62	.076	.077	.079	.080	.082	.083	.085	.086	.088	.089	.091	.092	.094
64	.080	.082	.083	.085	.086	.088	.090	.091	.093	.094	.096	.098	.099
66	.085	.086	.088	.090	.091	.093	.095	.096	.098	.100	.101	.103	.105
68	.089	.091	.093	.094	.096	.098	.100	.102	.103	.105	.107	.109	.110
70	.094	.095	.097	.099	.101	.103	.105	.107	.109	.110	.112	.114	.116
71	.096	.098	.100	.102	.103	.105	.107	.109	.111	.113	.115	.117	.119
72	.098	.100	.102	.104	.106	.108	.110	.112	.114	.116	.118	.120	.122
73	.100	.102	.104	.106	.108	.110	.112	.115	.116	.118	.120	.122	.124
74	.103	.105	.107	.109	.111	.113	.115	.117	.119	.121	.123	.125	.127
75	.105	.107	.109	.111	.113	.115	.117	.119	.122	.124	.126	.128	.130
76	.107	.109	.111	.113	.116	.118	.120	.122	.124	.126	.128	.131	.133
77	.109	.112	.114	.116	.118	.120	.122	.125	.127	.129	.131	.133	.136
78	.112	.114	.116	.118	.120	.123	.125	.127	.129	.132	.134	.136	.138
79	.114	.116	.118	.121	.123	.125	.127	.130	.132	.134	.137	.139	.141
80	.116	.118	.121	.123	.125	.128	.130	.132	.135	.137	.139	.142	.144
81	.118	.121	.123	.125	.128	.130	.132	.135	.137	.140	.142	.144	.147
82	.121	.123	.125	.128	.130	.133	.135	.137	140	.142	.145	.147	.149
83	.123	.125	.128	.130	.133	.135	.138	.140	.142	.145	.147	.150	.152
84	.125	.128	.130	.133	.135	.138	.140	.143	.145	.148	.150	.153	.155
85	.127	.130	.132	.135	.137	.140	.143	.145	148	.150	.153	.155	.158
86	.130	.132	.135	.137	.140	.142	.145	.148	.150	.153	.155	.158	.161
87	.132	.134	.137	.140	.142	.145	.148	.150	.153	.155	.158	.161	.163
88	.134	.137	.139	.142	.145	.147	.150	.153	.155	.158	.161	.163	.166
89	.136	.139	.142	.144	.147	.150	.153	.155	.158	.161	.164	.166	.169
90	.138	.141	.144	.147	.150	.152	.155	.158	.161	.163	.166	.169	.172
92	.143	.146	.149	.152	.154	.157	.160	.163	.166	.169	.172	.174	.177
94	.147	.150	.153	.156	.159	.162	.165	.168	.171	.174	.177	.180	.183
96	.152	.155	.158	.161	.164	.167	.170	.173	.176	.179	.182	.185	.188
98	.156	.160	.163	.166	.169	.172	.175	.178	.181	.185	.188	.191	.194
100	.161	.164	.167	.171	.174	.177	.180	.183	.187	.190	.193	.196	.200

Condensed from circular F, U. S. Weather Bureau, 6th ed 1939.

Correction of Small Bore Single-Tube Mercury Columns for Capillarity

Table II

I D Tube Inches	Height of Meniscus—Inches							
	.01	.02	.03	.04	.05	.06	.07	.08
	Correction to be added to Hg Column Reading—Inches							
.15	.024	.047	.069	.092	.116			
.20	.011	.022	.033	.045	.059	.078		
.25	.006	.012	.019	.028	.037	.047	.059	
.30	.004	.008	.013	.018	.023	.029	.035	.042
.40		.004	.006	.008	.010	.012	.014	.016
.50			.002	.004	.005	.006	.006	.007

(From Smithsonian Physical Tables—1933)

Explanation of Correction Tables for Mercurial Barometers

TABLE I—Examples of Use

Reading of barometer at 75°F	29.964″
Temperature correction (Table I)	—.126″
Barometer corrected to 32°F	29.838″
Reading of Mercury column at 97°F	28.120″
Temperature correction (Table I)	—.173″
Vacuum corrected to 32°F	27.947″
Absolute pressure (29.838—27.947)	1.891″

TABLE II—Example of Use

Suppose above mercury column had a single tube of 5/32″ bore and the estimated height of meniscus was .05″

Correction for capillarity (Table II)	+.102″
Vacuum corrected for capillarity (27.947+.102)	28.049″
Absolute pressure (29.838—28.049)	1.789″

NOTE:—Always read the top of the meniscus and add the capillarity correction to this vacuum column reading. There is no correction on double tube mercury columns or manometers.

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Miscellaneous

Other barometer corrections include those for latitude, altitude and difference in elevation between barometer and datum plane. These are given on the following page.

Tables I, III, IV and V apply to mercurial barometers.

Tables V applies to aneroid barometers.

Table II applies to small-bore, single-tube mercury columns. U-tubes and manometers, in which both legs have approximately the same bore, and large-bore, single-tube columns do not require capillarity correction. The temperature correction from Table I applies to any mercury column when brass scales calibrated in inches at 62°F and a density factor for mercury based on 32°F are used.

Tables III and IV apply to all mercury columns in which a density factor based on 45° latitude and sea level altitude is used. The corrections are small and are usually ignored or taken into account by using a density factor based on the latitude and altitude of the datum point.

In general, aneroid barometers are not satisfactory for accurate testing. If one is used, it should be compensated for temperature and frequently calibrated against a standard mercurial barometer, as a violent knock or shaking may introduce a substantial error.

Correction of Mercurial Barometer for Latitude in inches Hg to reduce to 45° Latitude

To be added to barometer reading for latitudes above 45°
To be subtracted from barometer reading for latitudes below 45°

TABLE III

Latitude		Reading of the barometer, in inches												
		18	19	20	21	22	23	24	25	26	27	28	29	30
°	°													
0	90	0.047	0.049	0.052	0.054	0.057	0.060	0.062	0.065	0.067	0.070	0.073	0.075	0.078
5	85	.046	.048	.051	.054	.056	.059	.061	.064	.066	.069	.071	.074	.077
6	84	.046	.048	.051	.053	.056	.058	.061	.063	.066	.068	.071	.073	.076
7	83	.045	.048	.050	.053	.055	.058	.060	.063	.065	.068	.070	.073	.075
8	82	.045	.047	.050	.052	.055	.057	.060	.062	.065	.067	.070	.072	.075
9	81	.044	.047	.049	.052	.054	.057	.059	.062	.064	.067	.069	.071	.074
10	80	.044	.046	.049	.051	.054	.056	.058	.061	.063	.066	.068	.071	.073
11	79	.043	.046	.048	.050	.053	.055	.058	.060	.062	.065	.067	.070	.072
12	78	.043	.045	.047	.050	.052	.054	.057	.059	.062	.064	.066	.069	.071
13	77	.042	.044	.047	.049	.051	.054	.056	.058	.061	.063	.065	.068	.070
14	76	.041	.043	.046	.048	.050	.053	.055	.057	.059	.062	.064	.066	.069
15	75	.040	.043	.045	.047	.049	052	.054	.056	.058	.061	.063	.065	.067
16	74	.040	.042	.044	.046	.048	.051	.053	.055	.057	.059	.061	.064	.066
17	73	.039	.041	.043	.045	.047	.049	.052	.054	.056	.058	.060	.062	.064
18	72	.038	.040	.042	.044	.046	.048	.050	.052	.054	.057	.059	.061	.063
19	71	.037	.039	.041	.043	.045	.047	.049	.051	.053	.055	.057	.059	.061
20	70	.036	.038	.040	.042	.044	.046	.048	.050	.052	.054	.056	.058	.060
21	69	.035	.037	.038	.040	.042	.044	.046	.048	.050	.052	.054	.056	.058
22	68	.034	.035	.037	.039	.041	.043	.045	047	.048	.050	.052	.054	.056
23	67	.032	.034	.036	.038	.040	.041	.043	.045	.047	.049	.050	.052	.054
24	66	.031	.033	.035	.036	.038	.040	.042	.043	.045	.047	.049	.050	.052
25	65	.030	.032	.033	.035	.037	.038	.040	.042	.043	.045	.047	.048	.050
26	64	.029	.030	.032	.033	.035	.037	.038	.040	.041	.043	.045	.046	.048
27	63	.027	.029	.030	.032	.033	.035	.037	.038	.040	.041	.043	.044	.046
28	62	.026	.028	.029	.030	.032	.033	.035	.036	.038	.039	.041	.042	.043
29	61	.025	.026	.027	.029	.030	.032	.033	.034	.036	.037	.038	.040	.041
30	60	.023	.025	.026	.027	.028	.030	.031	.032	.034	.035	.036	.038	.039
31	59	.022	.023	.024	.026	.027	.028	.029	.030	.032	.033	.034	.035	.036
32	58	.020	.022	.023	.024	.025	.026	.027	.028	.030	.031	.032	.033	.034
33	57	.019	.020	.021	.022	.023	.024	.025	.026	.027	.028	.029	.031	.032
34	56	.017	.018	.019	.020	.021	.022	.023	.024	.025	.026	.027	.028	.029
35	55	.016	.017	.018	.019	.019	.020	.021	.022	.023	.024	.025	.026	.027
36	54	.014	.015	.016	.017	.018	.018	.019	.020	.021	.022	.022	.023	.024
37	53	.013	.014	.014	.015	.016	.016	.017	.018	.019	.019	.020	.021	.021
38	52	.011	.012	.013	.013	.014	.014	.015	.016	.016	.017	.018	.018	.019
39	51	.010	.010	.011	.011	.012	.012	.013	.013	.014	.015	.015	.016	.016
40	50	.008	.009	.009	.009	.010	.010	.011	.011	.012	.012	.013	.013	.013
41	49	.006	.007	.007	.008	.008	.008	.009	.009	.009	.010	.010	.010	.011
42	48	.005	.005	.005	.006	.006	.006	.006	.007	.007	.007	.008	.008	.008
43	47	.003	.003	.004	.004	.004	.004	.004	.005	.005	.005	.005	.005	.005
44	46	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.003	.003	.003
45	45	.000	.000	.000	.000	.000	000	.000	.000	.000	.000	.000	.000	.000

Correction of Mercurial Barometer for Altitude

inches Hg to be subtracted from barometer reading

TABLE IV

Altitude ft	Reading of barometer, inches						
	25	26	27	28	29	30	31
0	....	....	.000	.000	.000	.000	.000
500	....	....	.001	.001	.001	.001	.001
1000	....	....	.002	.002	.002	.002	.002
1500	....	.002	.002	.003	.003	.003	
2000	....	.003	.003	.003	.003	.004	
2500	.004	.004	.004	.004	.004		
3000	.004	.005	.005	.005	.005		
3500	.005	.005	.006	.006			
4000	.006	.006	.006	.007			
4500	.007	.007	.007				
5000	.007	.008	.008				
5500	.008	.009					
6000	.009	.009					
6500	.010						
7000	.010						

Elevation Correction for Barometer

In inches Hg per 100 ft difference in elevation
To be added to barometer reading when barometer is above datum plane.
To be subtracted from barometer reading when barometer is below datum plane

TABLE V

Altitude ft	Temperature, °F									
	0	10	20	30	40	50	60	70	80	90
0	.122	.119	.117	.114	.112	.110	.108	.106	.104	.102
1000	.118	.115	.113	.110	.108	.106	.104	.102	.100	.098
2000	.113	.110	.108	.106	.104	.102	.100	.098	.096	.094
3000	.108	.106	.104	.102	.100	.089	.096	.094	.092	.090
4000	.104	.102	.100	.098	.096	.094	.092	.090	.088	.086
5000	.100	.098	.096	.094	.092	.090	.088	.086	.084	.082
6000	.096	.094	.092	.090	.088	.086	.084	.082	.081	.080
7000	.093	.091	.089	.087	.085	.084	.082	.080	.079	.078

Example of use of Tables III, IV and V.

Assume a barometer reading of 29.013″ Hg at 70°F. 1000 ft altitude, 25° altitude and 30 ft above the datum plane for which a reading is desired.

Barometer reading..29.013″
Latitude correction (TABLE III)..............................—.048″
Altitude correction (TABLE IV)...............................—.002″
Elevation correction (TABLE V) (.3×.102)....................+.031″
Temperature correction (TABLE I)...........................—.019″
Corrected barometer (To 32° F,
970 ft altitude, and 45° latitude)...........................28.885″

Atmospheric Pressures and Barometer Readings at Different Altitudes (Approximate Values)

Altitude Below or Above Sea Level Feet	Barometer Reading Inches Merc at 32°F	Atmospheric Pressure Lb-Sq In	Equivalent Head of Water (75°) Feet	Boiling Point of Water °F
−1000	31.02	15.2	35.2	213.8
− 500	30.47	15.0	34.7	212.9
0	29.921	14.7	34.0	212.0
+ 500	29.38	14.4	33.4	211.1
+1000	28.86	14.2	32.8	210.2
1500	28.33	13.9	32.2	209.3
2000	27.82	13.7	31.6	208.4
2500	27.31	13.4	31.0	207.4
3000	26.81	13.2	30.5	206.5
3500	26.32	12.9	29.9	205.6
4000	25.84	12.7	29.4	204.7
4500	25.36	12.4	28.8	203.8
5000	24.89	12.2	28.3	202.9
5500	24.43	12.0	27.8	201.9
6000	23.98	11.8	27.3	201.0
6500	23.53	11.5	26.7	200.1
7000	23.09	11.3	26.2	199.2
7500	22.65	11.1	25.7	198.3
8000	22.22	10.9	25.2	197.4
8500	21.80	10.7	24.8	196.5
9000	21.38	10.5	24.3	195.5
9500	20.98	10.3	23.8	194.6
10,000	20.58	10.1	23.4	193.7
15,000	16.88	8.3	19.1	184
20,000	13.75	6.7	15.2	—
30,000	8.88	4.4	10.2	—
40,000	5.54	2.7	6.3	—
50,000	3.44	1.7	3.9	—

Weights of Cast Iron Flanged Pipe

Nominal size inches	Class A 43 lb per sq in press			Class B 86 lb per sq in press			Class C 130 lb per sq in press			Class D 173 lb per sq in press			Class F 260 lb per sq in press			Class H 347 lb per sq in press		
	Thickness inches	Wt lb per foot	Wt lb per single flange	Thickness inches	Wt lb per foot	Wt lb per single flange	Thickness inches	Wt lb per foot	Wt lb per single flange	Thickness inches	Wt lb per foot	Wt lb per single flange	Thickness inches	Wt lb per foot	Wt lb per single flange	Thickness inches	Wt lb per foot	Wt lb per single flange
3	.39	13.0	6.4	.42	14.6	6.2	.45	15.5	6.2	.48	16.4	6.2						
4	.42	18.0	11.1	.45	20.1	10.7	.48	21.3	10.7	.52	22.8	10.7						
6	.44	27.9	15.0	.48	31.1	14.4	.51	32.9	14.4	.55	35.3	14.4	.61	39.5	30.6	.69	45.2	29.9
8	.46	38.7	23.1	.51	42.7	23.1	.56	48.0	22.0	.60	51.2	22.0	.71	60.6	45.3	.80	69.0	44.1
10	.50	51.9	32.2	.57	58.8	32.2	.62	65.5	30.6	.68	71.4	30.6	.80	84.7	65.7	.92	98.5	63.6
12	.54	67.0	47.7	.62	76.4	47.7	.68	85.4	45.6	.75	93.7	45.6	.89	112.5	94.1	1.04	132.9	90.7
14	.57	82.3	58.1	.66	94.7	58.1	.74	108.1	55.1	.82	119.2	55.1	.99	145.5	118.8	1.16	172.4	114.0
16	.60	98.8	73.2	.70	114.6	73.2	.80	113.3	69.1	.89	147.5	69.1	1.08	180.8	147.3	1.27	215.0	140.8
18	.64	118.3	78.1	.75	137.8	78.1	.87	162.4	72.8	.96	178.4	72.8	1.17	219.8	179.6	1.39	264.2	170.8
20	.67	137.4	98.8	.80	163.1	99.8	.92	190.6	92.9	1.03	212.3	92.9	1.27	264.8	215.5	1.51	318.4	204.4
24	.76	186.5	137.2	.89	217.3	137.2	1.04	257.6	126.8	1.16	286.0	126.8	1.45	361.7	321.4			
30	.88	266.1	214.4	1.03	312.6	207.2	1.26	366.9	196.0	1.37	421.2	186.4	1.73	538.0	446.9			
36	.99	358.7	327.4	1.15	418.7	314.8	1.36	497.7	299.9	1.58	581.9	282.5						
42	1.10	464.6	458.5	1.28	542.2	444.2	1.54	657.4	415.4	1.78	764.1	392.1						
48	1.26	608.0	555.9	1.42	687.2	538.9	1.71	832.7	504.4	1.96	960.8	470.8						

Flanges classes A to D inclusive drilled to American 1928, 125 lb std.
Flanges Classes F and H drilled to American 1928, 250 lb standard.
Courtesy of the Warren Foundry & Pipe Corp.

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American Standard C I Pipe Flanges

All dimensions given in inches

Nominal Pipe Size Inches	Dia of Flange	Dia of Bolt Circle	No of Bolts	*25 lb Standard			**125 lb Standard		
				Flange Thickness	Size Bolts	Lgth Bolts	Flange Thickness	Size Bolts	Lgth Bolts
1	4-¼	3-⅛	4				7/16	½	1-¾
1-¼	4-⅝	3-½	4				½	½	2
1-½	5	3-⅞	4				9/16	½	2
2	6	4-¾	4				⅝	⅝	2-¼
2-½	7	5-½	4				11/16	⅝	2-½
3	7-½	6	4				¾	⅝	2-½
3-½	8-½	7	8				13/16	⅝	2-¾
4	9	7-½	8	¾	⅝	2-¼	15/16	⅝	3
5	10	8-½	8	¾	⅝	2-¼	15/16	¾	3
6	11	9-½	8	¾	⅝	2-¼	1	¾	3-¼
8	13-½	11-¾	8	¾	⅝	2-¼	1-⅛	¾	3-½
10	16	14-¼	12	⅞	⅝	2-½	1-3/16	⅞	3-¾
12	19	17	12	1	⅝	2-¾	1-¼	⅞	3-¾
14 OD	21	18-¾	12	1-⅛	¾	3-¼	1-⅜	1	4-¼
16 OD	13-½	21-¼	16	1-⅛	¾	3-¼	1-7/16	1	4-½
18 OD	25	22-¾	16	1-¼	¾	3-½	1-9/16	1-⅛	4-¾
20 OD	27-½	25	20	1-¼	¾	3-½	1-11/16	1-⅛	5
24 OD	32	29-½	20	1-⅜	¾	3-¾	1-⅞	1-¼	5-½
30 OD	38-¾	36	28	1-½	⅞	4-¼	2-⅛	1-¼	6-¼
36 OD	46	42-¾	32	1-⅝	⅞	5	2-⅜	1-½	7
42 OD	53	49-½	36	1-¾	1	5-¼	2-⅝	1-½	7-½
48 OD	59-½	56	44	2	1	5-½	2-¾	1-½	7-¾
54 OD	66-¼	62-¾	44	2-¼	1	5-¾	3	1-¾	8-½
60 OD	73	69-¼	52	2-¼	1-⅛	6	3-⅛	1-¾	8-¾
72 OD	86-½	82-½	60	2-½	1-⅛	6-¼	3-½	1-¾	9-½
84 OD	99-¾	95-½	64	2-¾	1-¼	7-¼	3-⅞	2	10-½
6 OD	13-¼	108-½	68	3	1-¼	7-¾	4-¼	2-¼	11-½

These flanges are all with plain face.

*43 psi non-shock hydraulic working pressure through 36″ size.

**175 psi non-shock hydraulic working pressure for sizes 1″ through 12″. 150 psi for sizes 14″ through 48″.

From American Standards Association "Cast Iron Pipe Flanges and Flanged Fittings" B 16b2—1931 for 25 lb. B16.1—1948 for 125 lb.

American Standard C I Pipe Flanges (Cont.)

All dimensions given in inches

Nominal pipe size	*250 lb standard					**800 lb standard				
	Flange		Bolt circle dia	Bolts		Flange		Bolt circle dia	Bolts	
	dia	thickness†		No	size	dia	thickness††		No	size
1	4⅞	11/16	3½	4	⅝					
1¼	5¼	¾	3⅞	4	⅝					
1½	6⅛	13/16	4½	4	¾					
2	6½	⅞	5	8	⅝	6½	1¼	5	8	⅝
2½	7½	1	5⅞	8	¾	7½	1⅜	5⅞	8	¾
3	8¼	1⅛	6⅝	8	¾	8¼	1½	6⅝	8	¾
3½	9	1 3/16	7¼	8	¾	9	1⅝	7¼	8	⅞
4	10	1¼	7⅞	8	¾	10¾	1⅞	8½	8	⅞
5	11	1⅜	9¼	8	¾	13	2⅛	10½	8	1
6	12½	1 7/16	10⅝	12	¾	14	2¼	11½	12	1
8	15	1⅝	13	12	⅞	16½	2½	13¾	12	1⅛
10	17½	1⅞	15¼	16	1	20	2⅞	17	16	1¼
12	20½	2	17¾	16	1⅛	22	3	19¼	20	1¼
14OD	23	2⅛	20¼	20	1⅛					
16OD	25½	2¼	22½	20	1¼					
18OD	28	2⅜	24¾	24	1¼					
20OD	30½	2½	27	24	1¼					
24OD	36	2¾	32	24	1½					
30OD	43	3	39¼	28	1¾					
36OD	50	3⅜	46	32	2					
42OD	57	3 11/16	52¾	36	2					
48OD	65	4	60¾	40	2					

*400 psi non-shock hydraulic working pressure through 12″ size. 300 psi above 12″ size.

**800 psi non-shock hydraulic working pressure at ordinary temperatures.

†250 lb std flanges have 1/16 in raised face. This is included in flange thickness.

††800 lb std flanges are of two types; raised face and male-female. Raised face and male side of male-female have ¼ in raised face which is not included in flange thickness. Female side is faced 3/16 in deep within a raised face not included in flange thickness.

From American Standards Association "Cast Iron Pipe Flanges and Flanged Fittings" B16b-1944 and B16b1-1931.

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American Standard Steel Pipe Flanges
All dimensions in inches

Nom. pipe dia	Flange rating lb	Dia of flange	Flange thick-ness*	Dia bolt circle	No of bolts	Size of bolts	Nom. pipe dia	Flange rating lb	Dia of flange	Flange thick-ness*	Dia bolt circle	No of bolts	Size of bolts
½	150	3½	7/16	2⅜	4	½	2	150	6	¾	4¾	4	⅝
	300	3¾	9/16	2⅝	4	½		300	6½	⅞	5	8	⅝
	400	3¾	9/16	2⅝	4	½		400	6½	1	5	8	⅝
	600	3¾	9/16	2⅝	4	½		600	6½	1	5	8	⅝
	900	4¾	⅞	3¼	4	¾		900	8½	1½	6½	8	⅞
	1500	4¾	⅞	3¼	4	¾		1500	8½	1½	6½	8	⅞
	2500	5¼	1 3/16	3½	4	¾		2500	9¼	2	6¾	8	1
¾	150	3⅞	½	2¾	4	½	2½	150	7	⅞	5½	4	⅝
	300	4⅝	⅝	3¼	4	⅝		300	7½	1	5⅞	8	¾
	400	4⅝	⅝	3¼	4	⅝		400	7½	1⅛	5⅞	8	¾
	600	4⅝	⅝	3¼	4	⅝		600	7½	1⅛	5⅞	8	¾
	900	5⅛	1	3½	4	¾		900	9⅝	1⅝	7½	8	1
	1500	5⅛	1	3½	4	¾		1500	9⅝	1⅝	7½	8	1
	2500	5½	1¼	3¾	4	¾		2500	10½	2¼	7¾	8	1⅛
1	150	4¼	9/16	3⅛	4	½	3	150	7½	15/16	6	4	⅝
	300	4⅞	11/16	3½	4	⅝		300	8¼	1⅛	6⅝	8	¾
	400	4⅞	11/16	3½	4	⅝		400	8¼	1¼	6⅝	8	¾
	600	4⅞	11/16	3½	4	⅝		600	8¼	1¼	6⅝	8	¾
	900	5⅞	1⅛	4	4	⅞		900	9½	1½	7½	8	⅞
	1500	5⅞	1⅛	4	4	⅞		1500	10½	1⅞	8	8	1⅛
	2500	6¼	1⅜	4¼	4	⅞		2500	12	2⅝	9	8	1¼
1¼	150	4⅝	⅝	3½	4	½	3½	150	8½	15/16	7	8	⅝
	300	5¼	¾	3⅞	4	⅝		300	9	1 3/16	7¼	8	¾
	400	5¼	13/16	3⅞	4	⅝		400	9	1⅜	7¼	8	⅞
	600	5¼	13/16	3⅞	4	⅝		600	9	1⅜	7¼	8	⅞
	900	6¼	1⅛	4⅜	4	⅞		900	......	......	......	......	......
	1500	6¼	1⅛	4⅜	4	⅞		1500	......	......	......	......	......
	2500	7¼	1½	5⅛	4	1		2500	......	......	......	......	......
1½	150	5	11/16	3⅞	4	½	4	150	9	15/16	7½	8	⅝
	300	6⅛	13/16	4½	4	¾		300	10	1¼	7⅞	8	¾
	400	6⅛	⅞	4½	4	¾		400	10	1⅜	7⅞	8	⅞
	600	6⅛	⅞	4½	4	¾		600	10¾	1½	8½	8	⅞
	900	7	1¼	4⅞	4	1		900	11½	1¾	9¼	8	1⅛
	1500	7	1¼	4⅞	4	1		1500	12¼	2⅛	9½	8	1¼
	2500	8	1¾	5¾	4	1⅛		2500	14	3	10¾	8	1½

American Standard Steel Pipe Flanges
All dimensions in inches

Nom. pipe dia	Flange rating lb	Dia of flange	Flange thickness*	Dia bolt circle	No of bolts	Size of bolts	Nom. pipe dia	Flange rating lb	Dia of flange	Flange thickness*	Dia bolt circle	No of bolts	Size of bolts
	150	10	15/16	8 1/2	8	3/4		150	21	1 3/8	18 3/4	12	1
	300	11	1 3/8	9 1/4	8	3/4		300	23	2 1/8	20 1/4	20	1 1/8
	400	11	1 1/2	9 1/4	8	7/8		400	23	2 3/8	20 1/4	20	1 1/4
5	600	13	1 3/4	10 1/2	8	1	14 OD	600	23 3/4	2 3/4	20 3/4	20	1 3/8
	900	13 3/4	2	11	8	1 1/4		900	25 1/4	3 3/8	22	20	1 1/2
	1500	14 3/4	2 7/8	11 1/2	8	1 1/2		1500	29 1/2	5 1/4	25	16	2 1/4
	2500	16 1/2	3 3/8	12 3/4	8	1 3/4		......	......	......	......	......	......
	150	11	1	9 1/2	8	3/4		150	23 1/2	1 7/16	21 1/4	16	1
	300	12 1/2	1 7/16	10 5/8	12	3/4		300	25 1/2	2 1/4	22 1/2	20	1 1/4
	400	12 1/2	1 5/8	10 5/8	12	7/8		400	25 1/2	2 1/2	22 1/2	20	1 3/8
6	600	14	1 7/8	11 1/2	12	1	16 OD	600	27	3	23 3/4	20	1 1/2
	900	15	2 3/16	12 1/2	12	1 1/8		900	27 3/4	3 1/2	24 1/4	20	1 5/8
	1500	15 1/2	3 1/4	12 1/2	12	1 3/8		1500	32 1/2	5 3/4	27 3/4	16	2 1/2
	2500	19	4 1/4	14 1/2	8	2		......	......	......	......	......	......
	150	13 1/2	1 1/8	11 3/4	8	3/4		150	25	1 9/16	22 3/4	16	1 1/8
	300	15	1 5/8	13	12	7/8		300	28	2 3/8	24 3/4	24	1 1/4
	400	15	1 7/8	13	12	1		400	28	2 5/8	24 3/4	24	1 3/8
8	600	16 1/2	2 3/16	13 3/4	12	1 1/8	18 OD	600	29 1/4	3 1/4	25 3/4	20	1 5/8
	900	18 1/2	2 1/2	15 1/2	12	1 3/8		900	3	4	27	20	7/8
	1500	19	3 5/8	15 1/2	12	1 5/8		1500	36	6 3/8	30 1/2	16	2 3/4
	2500	21 3/4	5	17 1/4	12	2		......	......	......	......	......	......
	150	16	1 3/16	14 1/4	12	7/8		150	27 1/2	1 11/16	25	20	1 1/8
	300	17 1/2	1 7/8	15 1/4	16	1		300	30 1/2	2 1/2	27	24	1 1/4
	400	17 1/2	2 1/8	15 1/4	16	1 1/8		400	30 1/2	2 3/4	27	24	1 1/2
10	600	20	2 1/2	17	16	1 1/4	20 OD	600	32	3 1/2	28 1/2	24	1 5/8
	900	21 1/2	2 3/4	18 1/2	16	1 3/8		900	33 3/8	4 1/4	29 1/2	20	2
	1500	23	4 1/4	19	12	1 7/8		1500	38 3/4	7	32 3/4	16	3
	2500	26 1/2	6 1/2	21 1/4	12	2 1/2		......	......	......	......	......	......
	150	19	1 1/4	17	12	7/8		150	32	1 7/8	29 1/2	20	1 1/4
	300	20 1/2	2	17 3/4	16	1 1/8		300	36	2 3/4	32	24	1 1/2
	400	20 1/2	2 1/4	17 3/4	16	1 1/4		400	36	3	32	24	1 3/4
12	600	22	2 5/8	19 1/4	20	1 1/4	24 OD	600	37	4	33	24	1 7/8
	900	24	3 1/8	21	20	1 3/8		900	41	5 1/2	35 1/2	20	2 1/2
	1500	26 1/2	4 7/8	22 1/2	16	2		1500	46	8	39	16	3 1/2
	2500	30	7 1/4	24 3/8	12	2 3/4		......	......	......	......	......	......

*Flange thickness on 150 and 300 lb fittings includes a raised face of 1/16 in. On 400 to 2500 lb fittings there is a raised face of 1/4 in which is not included in flange thickness. On fittings with ring joints there is a raised face equal to the depth of the ring groove. This is not included in flange thickness. The depth of the ring groove varies from 7/32 to 11/16 in on various size and pressure fittings. The height of the ring itself will vary from 7/16 to 1 3/4 in on different size and pressure fittings.

From American Standards Association "Steel Pipe Flanges and Flanged Fittings" B16.5-1953.

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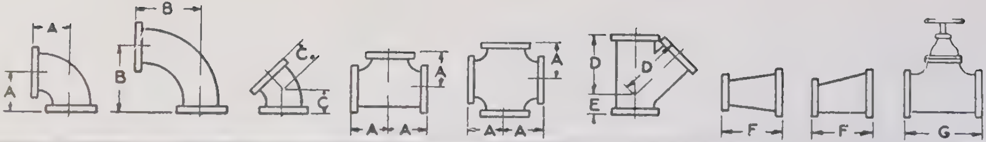
General Dimensions

25 and 125 lb Standard Cast Iron Flanged Fittings
All dimensions in inches



Size	1	1¼	1½	2	2½	3	3½	4	5	6	7	8	9	10	12
A Elbows, Tees & Crosses	3½	3¾	4	4½	5	5½	6	6½	7½	8	8½	9	10	11	12
B Long Radius Elbows	5	5½	6	6½	7	7¾	8½	9	10¼	11½	12¾	14	15¼	16½	19
C C to F 45° Elbows	1¾	2	2¼	2½	3	3	3½	4	4½	5	5½	5½	6	6½	7½
D C to F 45° Laterals	5¾	6¼	7	8	9½	10	11½	12	13½	14½	16½	17½	19½	20½	24½
E C to F 45° Laterals	1¾	1¾	2	2½	2½	3	3	3	3½	3½	4	4½	4½	5	5½
F F to F Reducers				5	5½	6	6½	7	8	9	10	11	11½	12	14
G F to F Gate Valves Std Chapman No 571				7	7½	8	8½	9	10	10½	11	11½	2	13	14
Size	**14**	**16**	**18**	**20**	**24**	**30**	**36**	**42**	**48**	**54**	**60**	**72**			
A Elbows, Tees & Crosses	14	15	16½	18	22	25	28	31	34	39	44	53			
B Long Radius Elbows	21½	24	26½	29	34	41½	49	56½	64	71½	79	94			
C C to F 45° Elbows	7½	8	8½	9½	11	15	18	21	24	27	30	36			
D C to F 45° Laterals	27	30	32	35	40½	49									
E C to F 45° Laterals	6	6½	7	8	9	10									
F F to F Reducers	16	18	19	20	24	30	36	42	48						
G Gate Valves, Low Press Chapman No 250 B M.	11½	12	12½	13	13¼	15	16	17½	19½	21	25	28½			

American Standards Association "Cast Iron Pipe Flanges and Fittings" except dimension "G".
The National Bureau of Standards has recommended the elimination of some sizes on certain of these fittings.
Dimensions above 48″ apply to 25 lb only. Twenty-five lb Standard starts at 4″.
Sizes 7″ and 9″ are eliminated from the American Standard.
Letters A, B, C, D, E, F and G represent dimensions. C to F designates centerline to flange. F to F designates flange to flange.

Approximate Weights
125 lb Standard Cast Iron Flanged Fittings

All weights given in pounds

Nominal Pipe Size	45° Ells	90° Ells	90° L R Ells	Tees	Crosses	Laterals	* Red Ells	* Reducers	Companion Flanges	Std Gate Valves
1	4	5	7	9	11	10			2	19
1¼	6	7	9	11	15	13			2	23
1½	8	9	11	15	19	17			3	27
2	12	14	16	21	28	25			5	31
2½	17	19	23	30	39	36			7	40
3	20	24	28	37	48	44	22	19	8	54
3½	27	31	37	49	63	59	28	24	11	67
4	36	41	48	64	82	75	37	31	14	84
5	45	52	62	81	105	96	48	39	17	110
6	60	68	85	105	135	125	60	50	22	140
8	94	110	145	165	210	210	90	77	31	240
10	145	175	230	270	330	340	150	120	45	380
12	220	250	350	380	470	520	220	180	63	590
14	270	350	470	530	650	680	320	250	82	770
16	360	470	670	700	850	950	420	340	105	1100
18	420	580	840	860	1040	1150	540	430	120	1300
20	540	740	1080	1100	1330	1480	680	520	150	1900
24	800	1160	1640	1730	2080	2080	1010	760	220	2800
30	1430	1850	2800	2710	3210	3680				4950
36	2280	2800	4450	4050	4750					8700
42	3380	4010	6610	5790	6710					
48	4680	5400	9250	7620	8740					

* Reduced to nearest standard pipe size.

The National Bureau of Standards has recommended the elimination of some sizes of certain of these fittings.

6

"Standard Weight" Welded and Seamless Steel Pipe

(Including Schedules 20, 30 and 40)

Schedule No.	Size	Diameter External	Diameter Internal	Thickness	Circumference External	Circumference Internal	Transverse area External	Transverse area Internal	Transverse area Metal	Length of pipe per square foot External surface	Length of pipe per square foot Internal surface	Wgt per ft of length
		Inches	Inches	Inches	Inches	Inches	Sq in	Sq in	Sq in	Feet	Feet	Lb.
40	1/8	.405	.269	.068	1.272	.845	.129	.057	.072	9.431	14.199	.24
	1/4	.540	.364	.088	1.696	1.144	.229	.104	.125	7.073	10.493	.42
	3/8	.675	.493	.091	2.121	1.549	.358	.191	.167	5.658	7.748	.57
	1/2	.840	.622	.109	2.639	1.954	.554	.304	.250	4.547	6.141	.85
	3/4	1.050	.824	.113	3.299	2.589	.866	.533	.333	3.637	4.635	1.13
	1	1.315	1.049	.133	4.131	3.296	1.358	.864	.494	2.904	3.641	1.68
	1 1/4	1.660	1.380	.140	5.215	4.335	2.164	1.495	.669	2.301	2.768	2.27
	1 1/2	1.900	1.610	.145	5.969	5.058	2.835	2.036	.799	2.010	2.372	2.72
	2	2.375	2.067	.154	7.461	6.494	4.430	3.555	1.075	1.608	1.847	3.68
	2 1/2	2.875	2.469	.203	0.032	7.757	6.492	4.788	1.704	1.328	1.547	5.79
	3	3.500	3.068	.216	10.966	9.638	9.621	7.393	2.228	1.091	1.245	7.58
	3 1/2	4.000	3.548	.226	12.566	11.146	12.566	9.886	2.680	.954	1.076	9.11
	4	4.500	4.026	.237	14.137	12.648	15.904	12.730	3.174	.848	.948	10.79
	5	5.563	5.047	.258	17.477	15.856	4.306	20.006	4.300	.686	.756	14.62
	6	6.625	6.065	.280	20.813	19.054	34.472	28.891	5.581	.576	.629	18.97
20	8	8.625	8.125	.250	27.096	25.53	58.43	51.87	6.56	.443	.470	22.36
30	8	8.625	8.081	.277	27.096	25.39	58.43	51.30	7.13	.443	.473	24.70
40	8	8.625	7.981	.322	27.096	25.07	58.43	50.03	8.40	.443	.478	28.55
20	10	10.75	10.25	.250	33.77	32.20	90.76	82.50	8.26	3.55	.372	28.04
30	10	10.75	10.136	.307	33.77	31.84	90.76	80.68	10.08	3.55	.377	34.24
40	10	10.75	10.02	.365	33.77	31.48	90.76	78.86	11.91	3.55	.381	40.48
20	12	12.750	12.250	.250	40.06	38.48	127.68	117.8	9.88	.299	.311	33.38

Table continued on next page.

Wrought Iron Welded pipe have same outside diameters but wall thickness varies from .002 to .007 thicker.

Based on ASA-B36.10—1950.

(The National Bureau of Standards has recommended the elimination of the 3½″ pipe size.)

"Standard Weight" Welded and Seamless Steel Pipe

(Including Schedules 20, 30 and 40)

Schedule No.	Size	Diameter External	Diameter Internal	Thickness	Circumference External	Circumference Internal	Transverse area External	Transverse area Internal	Transverse area Metal	Length of pipe per square foot External surface	Length of pipe per square foot Internal surface	Wgt per ft of length
		Inches	Inches	Inches	Inches	Inches	Sq in	Sq in	Sq in	Feet	Feet	Lb.
30	12	12.750	12.090	.330	40.06	37.97	127.68	114.8	12.88	.299	.316	43.77
40	12	12.750	11.938	.406	40.66	37.51	127.68	112.0	15.68	.299	.319	53.53
20	14O.D.	14.000	13.376	.312	43.98	42.01	153.94	140.5	13.44	.272	.285	45.68
30	14O.D.	14.000	13.250	.375	43.98	41.62	153.94	137.9	16.04	.272	.288	54.57
40	14O.D.	14.000	13.126	.438	43.98	41.21	153.94	125.2	18.74	.272	.291	63.37
20	16O.D.	16.000	15.376	.312	50.27	48.29	201.06	185.6	15.46	.238	.249	52.36
30	16O.D.	16.000	15.250	.375	50.27	47.90	201.06	182.6	18.46	.238	.250	62.58
40	16O.D.	16.000	15.000	.500	50.27	37.12	201.06	176.7	24.36	.238	.254	82.77
20	18O.D.	18.000	17.376	.312	56.55	54.60	254.47	237.2	17.27	.212	.220	59.03
30	18O.D.	18.000	17.126	.438	56.55	53.77	254.47	230.2	24.27	.212	.223	82.06
40	18O.D.	18.000	16.876	.562	56.55	52.98	254.47	223.5	30.97	.212	.227	104.75
20	20O.D.	20.000	19.250	.375	62.83	60.47	314.16	291.0	23.16	.191	.199	78.60
30	20O.D.	20.000	19.000	.500	62.83	59.69	314.16	283.6	30.56	.191	.201	104.13
40	20O.D.	20.000	18.814	.593	62.83	59.08	314.16	277.9	36.26	.191	.203	122.91

Wrought Iron Welded pipe have same outside diameters, but wall thickness .002 to .007 thicker.

Based on ASA-B36.10—1950.

6

"Extra Strong" Welded and Seamless Steel Pipe

(Including Schedules 80 and 160)

Schedule No.	Size	Diameter External	Diameter Internal	Thickness	Circumference External	Circumference Internal	Transverse area External	Transverse area Internal	Transverse area Metal	Length of pipe per square foot External surface	Length of pipe per square foot Internal surface	Wgt per ft of length
		Inches	Inches	Inches	Inches	Inches	Sq in	Sq in	Sq in	Feet	Feet	Lb.
	⅛	.405	.215	.095	1.272	.675	.129	.036	.093	9.431	17.766	.31
	¼	.540	.302	.119	1.696	.949	.229	.072	.157	7.073	12.648	.54
	⅜	.675	.423	.126	2.121	1.329	.358	.141	.217	5.658	9.030	.74
80	½	.840	.546	.147	2.64	1.715	.554	.234	.320	4.55	6.99	1.09
160	½	.840	.466	.187	2.64	1.464	.554	.171	.383	4 55	8.19	1.30
80	¾	1.050	.742	.154	3.30	2.331	.866	.433	.433	3.64	5.15	1.47
160	¾	1.050	.614	.218	3.30	1.930	.866	.296	.570	3.64	6.22	1.94
80	1	1.315	.957	.179	4.13	3.007	1.358	.719	.639	2.90	3.99	2.17
160	1	1.315	.815	250	4.13	2.561	1.358	.522	.836	2.90	4.69	2.84
80	1¼	1.660	1.278	.191	5.22	4.015	2.164	1.283	.881	2.30	2.99	3.00
160	1¼	1.660	1.160	.250	5.22	3.645	2.164	1 057	1.107	2.30	3.29	3.76
80	1½	1.900	1 500	.200	5.97	4.712	2 835	1.767	1.068	2.01	2.55	3.63
160	1½	1.900	1.338	281	5.97	4.205	2.835	1.406	1.429	2.01	2.86	4.86
80	2	2.375	1 939	.218	7 46	6 092	4.430	2.953	1.477	1.61	1.97	5.02
160	2	2.375	1 689	.343	7.46	5 307	4.430	2.241	2.189	1.61	2.26	7.44
80	2½	2.875	2.323	.276	9.03	7 298	6.492	4 238	2.254	1 33	1.64	7.66
160	2½	2.875	2.125	.375	9.03	6.676	6.492	3.545	2.947	1.33	1.80	10.01
80	3	3.5	2.900	.300	10.99	9.111	9.621	6 605	3.016	1.09	1.32	10.25

Table continued on next page.

Wrought Iron Welded pipe have same outside diameter but wall thickness varies .003 to .010 greater.

Based on ASA-B36.10—1950.

(The National Bureau of Standards has recommended the elimination of the 3½" pipe size.)

"Extra Strong" Welded and Seamless Steel Pipe

(Including Schedules 80, 120 and 160)

Schedule No.	Size	Diameter		Thickness	Circumference		Transverse area			Length of pipe per square foot		Wgt per ft of length
		External	Internal		External	Internal	External	Internal	Metal	External surface	Internal surface	
		Inches	Inches	Inches	Inches	Inches	Sq in	Sq in	Sq in	Feet	Feet	Lb.
160	3	3.5	2.626	.438	10.99	8.250	9.621	5.451	4.206	1.09	1.46	14.32
80	3½	4.0	3.364	.318	12.57	10.57	12.566	8.888	3.678	.95	1.14	12.51
80	4	4.500	3.826	.337	14.137	12.020	15.904	11.497	4.407	.848	.998	14.98
120	4	4.500	3.626	.438	14.137	11.39	15.904	10.325	5.679	.848	1.054	19.01
160	4	4.500	3.438	.531	14.137	10.80	15.904	9.282	6.622	.848	1.11	22.51
80	5	5.563	4.813	.375	17.477	15.120	24.31	18.19	6.12	.686	.793	20.78
120	5	5.563	4.563	.500	17.477	14.34	24.31	16.35	7.96	.686	.837	27.04
160	5	5.563	4.313	.625	17.477	13.55	24.31	14.61	9.70	.686	.897	32.96
80	6	6.625	5.761	.432	20.813	18.099	34.47	26.07	8.40	.576	.663	28.57
120	6	6.625	5.501	.562	20.813	17.29	34.47	23.77	10.70	.576	.695	36.39
160	6	6.625	5.189	.718	20.813	16.30	34.47	21.15	13.32	.576	.736	45.30
80	8	8.625	7.625	.500	27.096	23.955	58.43	45.66	12.77	.443	.500	43.39
120	8	8.625	7.189	.718	27.096	22.58	58.43	40.56	17.87	.443	.532	60.63
160	8	8.625	6.813	.906	27.096	21.40	58.43	36.44	21.99	.443	.561	74.69
80	10	10.75	9.564	.593	33.79	30.05	90.78	71.85	18.93	.356	.399	64.33
120	10	10.75	9.064	.843	33.79	28.48	90.78	64.50	26.28	.356	.421	89.20
160	10	10.75	8.500	1.125	33.79	26.70	90.78	56.86	33.92	.356	.449	115.65
80	12	12.75	11.376	.687	40.06	35.73	127.6	101.6	26.0	299	.336	88.51
120	12	12.75	10.75	1.000	40.06	33.79	127.6	90.78	36.82	.299	.355	125.49
160	12	12.75	10.126	1.312	40.06	31.81	127.6	80.46	47.14	.299	.377	160.27

Wrought Iron Welded pipe have same outside diameter but wall thickness varies from .003 to .010 greater.

Based on ASA-B36.10—1950.

6

Weights and Dimensions of Copper and Brass Pipe and Tubes

Nominal Size In	Copper Tubing							Copper and Brass Pipe—Regular Wt.				
	Outside Diam In	Type K		Type L		Type M		Outside Diam In	Inside Diam In	Weight per Ft—Lb		
		Inside Diam In	Wt. per Ft Lb	Inside Diam In	Wt. per Ft Lb	Inside Diam In	Wt. per Ft Lb			67% Copper	85% Copper	100% Copper
⅛	.250	.186	.085	.200	.068	.20	.068	.405	.281	.246	.253	.259
¼	.375	.311	.134	.315	.126	.325	.106	.540	.375	.437	.450	.460
⅜	.500	.402	.269	.430	.198	.450	.144	.675	.494	.612	.630	.643
½	.625	.527	.344	.545	.284	.569	.203	.840	.625	.911	.938	.957
⅝	.750	.652	.418	.666	.362	.690	.263					
¾	.875	.745	.641	.785	.454	.811	.328	1.050	.822	1.24	1.27	1.30
1	1.125	.995	.839	1.025	.653	1.055	.464	1.315	1.062	1.74	1.79	1.83
1¼	1.375	1.245	1.04	1.265	.882	1.291	.681	1.660	1.368	2.56	2.63	2.69
1½	1.625	1.481	1.36	1.505	1.14	1.571	.940	1.900	1.600	3.04	3.13	3.20
2	2.125	1.959	2.06	1.985	1.75	2.009	1.46	2.375	2.062	4.02	4.14	4.23
2½	2.625	2.435	2.92	2.465	2.48	2.495	2.03	2.875	2.500	5.83	6.00	6.14
3	3.125	2.907	4.00	2.945	3.33	2.981	2.68	3.500	3.062	8.31	8.56	8.75
3½	3.625	3.385	5.12	3.425	4.29	3.459	3.58	4.000	3.500	10.85	11.17	11.41
4	4.125	3.857	6.51	3.905	5.38	3.935	4.66	4.500	4.000	12.29	12.66	12.94
4½								5.000	4.500	13.74	14.15	14.46
5	5.125	4.805	9.67	4.875	7.61	4.907	6.66	5.563	5.063	15.40	15.85	16.21
6	6.125	5.741	13.87	5.845	10.20	5.881	8.91	6.625	6.125	18.44	18.99	19.41
7								7.625	7.062	23.92	24.63	25.17
8	8.125	7.583	25.90	7.725	19.29	7.785	16.46	8.625	8.000	30.05	30.95	31.63

The National Bureau of Standards has recommended the elimination of the 3½" and 4½" pipe sizes.

Capacities, in U.S. Gallons, of Cylinders of Various Diameters and Lengths

Diam. Inches	1″	1′	5′	6′	7′	8′	9′	10′	11′	12′	13′	14′	15′	16′	17′	18′	20′	22′	24′	Diam. Inches
	LENGTH OF CYLINDER																			
1	......	0.04	0.20	0.24	0.28	0.32	0.36	0.40	0.44	0.48	0.52	0.56	0.60	0.64	0.68	0.72	0.80	0.88	0.96	1
2	0.01	0.16	0.80	0.96	1.12	1.28	1.44	1.60	1.76	1.92	2.08	2.24	2.40	2.56	2.72	2.88	3.20	3.52	3.84	2
3	0.03	0.37	1.84	2.20	2.56	2.92	3.30	3.68	4.04	4.40	4.76	5.12	5.48	5.84	6.22	6.60	7.36	8.08	8.80	3
4	0.05	0.65	3.26	3.92	4.58	5.24	5.88	6.52	7.18	7.84	8.50	9.16	9.82	10.5	11.1	11.8	13.0	14.4	15.7	4
5	0.08	1.02	5.10	6.12	7.14	8.16	9.18	10.2	11.2	12.2	13.3	14.3	15.3	16.3	17.3	18.4	20.4	22.4	24.4	5
6	0.12	1.47	7.34	8.80	10.3	11.8	13.2	14.7	16.1	17.6	19.1	20.6	22.0	23.6	25.0	26.4	29.4	32.2	35.2	6
7	0.17	2.00	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	36.0	40.0	44.0	48.0	7
8	0.22	2.61	13.0	15.6	18.2	20.8	23.4	26.0	28.6	31.2	33.8	36.4	39.0	41.6	44.2	46.8	52.0	57.2	62.4	8
9	0.28	3.31	16.5	19.8	23.1	26.4	29.8	33.0	36.4	39.6	43.0	46.2	49.6	52.8	56.2	60.0	66.0	72.4	79.2	9
10	0.34	4.08	20.4	24.4	28.4	32.6	36.8	40.8	44.8	48.8	52.8	56.8	61.0	65.2	69.4	73.6	81.6	89.6	97.6	10
11	0.41	4.94	24.6	29.6	34.6	39.4	44.4	49.2	54.2	59.2	64.2	69.2	74.0	78.8	83.8	88.8	98.4	104.	118.	11
12	0.49	5.88	29.4	35.2	41.0	46.8	52.8	58.8	64.6	70.4	76.2	82.0	87.8	93.6	99.6	106.	118	129.	141.	12
13	0.57	6.90	34.6	41.6	48.6	55.2	62.2	69.2	76.2	83.2	90.2	97.2	104.	110	117.	124.	138.	152.	166.	13
14	0.67	8.00	40.0	48.0	56.0	64.0	72.0	80.0	88.0	96.0	104.	112.	120.	128.	136.	144.	160.	176.	192.	14
15	0.77	9.18	46.0	55.2	64.4	73.6	82.8	92.0	101	110	120.	129.	138	147	156.	166	184	202	220.	15
16	0.87	10.4	52.0	62.4	72.8	83.2	93.6	104.	114.	125.	135.	146.	156.	166.	177.	187.	208.	229.	250.	16
17	0.98	11.8	59.0	70.8	81.6	94.4	106.	118.	130.	142.	153.	163.	177.	189.	201.	212.	236.	260.	283.	17
18	1.10	13.2	66.0	79.2	92.4	106.	119.	132.	145.	158.	172.	185.	198.	211.	224.	240.	264.	290.	317.	18
19	1.23	14.7	73.6	88.4	103.	118.	132.	147.	162.	177.	192.	206.	221.	235.	250.	265.	294.	324.	354.	19
20	1.36	16.3	81.6	98.0	114.	130.	147.	163.	180.	196.	212.	229.	245.	261.	277.	294.	326.	359.	392.	20
21	1.50	18.0	90.0	108.	126.	144.	162.	180.	198.	216.	238.	252.	270.	288.	306.	324.	360.	396.	432.	21
22	1.65	19.8	99.0	119.	139.	158.	178.	198.	218.	238.	257.	277.	297.	317.	337.	356.	396.	436.	476.	22
23	1.80	21.6	108.	130.	151.	173.	194.	216.	238.	259.	281.	302.	324.	346.	367.	389.	432.	476.	518.	23
24	1.96	23.5	118.	141.	165.	188.	212.	235.	259.	282.	306.	330.	353.	376.	400.	424.	470.	518.	564.	24
25	2.12	25.5	128.	153.	179.	204.	230.	255.	281.	306.	332.	358.	383.	408.	434.	460.	510.	562.	612.	25
26	2.30	27.6	138.	166.	193.	221.	248.	276.	304.	331.	359.	386.	414.	442.	470.	496.	552.	608.	662.	26
27	2.48	29.7	148.	178.	208.	238.	267.	297.	326.	356.	386.	416.	426.	476.	504.	534.	594.	652.	712.	27
28	2.67	32.0	160.	192.	224.	256.	288.	320.	352.	384.	416.	448.	480.	512.	544.	576.	640.	704.	768.	28
29	2.86	34.3	171.	206.	240.	274.	309.	343.	377.	412.	446.	480.	514.	548.	584.	618.	686.	754.	824.	29
30	3.06	36.7	183	220	257	294	330	367	404	440	476	514	550	588	624.	660.	734	808.	880.	30
32	3.48	41.8	209.	251.	293.	334.	376.	418.	460.	502.	544.	586.	628.	668.	710.	752.	836.	920.	1004.	32
34	3.93	47.2	236.	283.	330.	378.	424.	472.	520.	566.	614.	660.	708.	756.	802.	848.	944.	1040.	1132.	34
36	4.41	52.9	264.	317.	370.	422.	476.	528.	582.	634	688	740.	793.	844.	898.	952.	1056.	1164.	1268.	36

Displacement per Stroke—In U.S. Gallons For Various Diameter Plungers

Stroke lengths in inches

Plunger Diam. in Inches	1	1½	2	2½	3	3½	4	5	6	7	8
.1875	.000119	.000179	.000239	.000299	.000358	....	....	....	....	....	....
.2500	.000212	.000318	.000424	.000530	.000636	....	....	....	....	....	....
.3125	.000332	.000498	.000664	.000830	.000996	....	....	....	....	....	....
.375	.000478	.000718	.000956	.001197	.001434	.001675	.001912	....	....	....	....
.4375	.000652	.000978	.001304	.00163	.001956	.002282	.00261	....	....	....	....
.500	.00085	.001275	.00170	.00212	.00255	.00297	.00340	.00425	.0051	.00595	.0068
.5625	.00107	.00161	.00215	.00268	.00322	.00376	.00430	.00538	.00645	.00752	.00860
.625	.00133	.00199	.00266	.00332	.00398	.00465	.00532	.00664	.00798	.00930	.01062
.6875	.00161	.00242	.00322	.00403	.00483	.00563	.00644	.00805	.00966	.01128	.01288
.750	.00191	.00286	.00382	.00477	.00573	.00668	.00764	.00955	.01146	.01337	.01527
.8125	.00224	.00336	.00448	.00560	.00672	.00785	.00896	.01120	.01345	.01570	.01792
.875	.00261	.00392	.00522	.00652	.00783	.00914	.01044	.01305	.01565	.01830	.02090
.9375	.00299	.00448	.00598	.00748	.00897	.01046	.01196	.01495	.01795	.02093	.02392
1.000	.00340	.00510	.00680	.00850	.01020	.01190	.01360	.0170	.0204	.0238	.0272
1.0625	.00383	.00574	.00770	.00959	.01151	.01343	.01535	.01915	.02298	.02681	.03064
1.125	.0043	.00645	.0086	.01076	.0129	.01506	.01721	.0215	.0258	.0301	.0344
1.1875	.00479	.00718	.00957	.01196	.01435	.01674	.01916	.02395	.02874	.03353	.03832
1.250	.00532	.00797	.0106	.0133	.0159	.0186	.0213	.0266	.0319	.0372	.0425
1.3125	.00586	.00879	.01172	.01465	.01758	.02051	.02344	.02930	.03516	.04102	.04688
1.375	.00643	.00965	.0129	.0161	.0193	.0225	.0257	.0322	.0386	.0451	.0514
1.4375	.00703	.01054	.01405	.01756	.02108	.02459	.02810	.03513	.04216	.04920	.05621
1.500	.00765	.01148	.0153	.0191	.02295	.0268	.0306	.0383	.0458	.0536	.0612
1.5625	.00830	.01245	.01660	.02075	.02490	.02905	.03320	.04150	.04980	.05810	.06640
1.625	.00898	.01348	.01798	.0225	.0270	.0314	.0360	.0450	.0538	.0628	.0718
1.6875	.00968	.01452	.01936	.02420	.02904	.03389	.03873	.04841	.05809	.06777	.07745
1.750	.01041	.01561	.02082	.02610	.0312	.0364	.0417	.0521	.0624	.0728	.0832
1.8125	.01117	.01675	.02234	.02792	.03351	.03909	.04468	.05585	.06702	.07819	.08936
1.875	.01196	.01794	.0239	.0299	.0359	.0418	.0478	.0598	.0718	.0837	.0957
1.9375	.01276	.01914	.02552	.03190	.03828	.04466	.05104	.06380	.07656	.08932	.10208
2.000	.01360	.0241	.0272	.0340	.0408	.0477	.0544	.0680	.0817	.0953	.1088
2.0625	.01446	.02169	.02892	.03615	.04338	.05061	.05784	.07230	.08676	.10122	.11568
2.125	.01536	.0230	.0307	.0384	.0461	.0537	.0614	.0768	.0922	.1075	.1228
2.1875	.01627	.02440	.03254	.04067	.04881	.05694	.06508	.08135	.09762	.11389	.13016
2.250	.01720	.0258	.0344	.0430	.0516	.0602	.0688	.0860	.1033	.1205	.1376
2.3125	.01818	.02727	.03636	.04545	.05454	.06363	.07272	.09090	.10908	.12726	.14528
2.375	.01917	.0287	.0383	.0478	.0575	.0671	.0767	.0958	.1148	.1340	.1532
2.500	.02125	.0319	.0425	.0532	.0637	.0744	.0850	.1063	.1274	.1488	.1700
2.625	.02347	.0352	.0469	.0587	.0704	.0822	.0939	.1173	.1409	.1643	.1878
2.750	.02573	.0386	.0514	.0643	.0772	.0900	.1029	.1287	.1544	.1802	.2058
2.875	.02810	.0421	.0562	.0702	.0843	.0983	.1124	.1405	.1686	.1967	.2248
3.000	.03060	.0459	.0612	.0765	.0918	.1071	.1224	.1530	.1836	.2142	.2448
3.125	.03320	.0498	.0664	.0830	.0996	.1162	.1328	.1660	.1992	.2324	.2656
3.250	.03590	.0538	.0718	.0897	.1077	.1256	.1436	.1795	.2154	.2513	.2872
3.375	.03872	.0581	.0774	.0968	.1162	.1355	.1549	.1936	.2323	.2710	.3097
3.500	.04165	.0624	.0833	.1042	.1249	.1458	.1666	.2083	.2499	.2916	.3332
3.625	.04470	.0670	.0894	.1117	.1341	.1565	.1788	.2235	.2682	.3129	.3576
3.750	.04780	.0717	.0956	.1195	.1434	.1673	.1912	.2390	.2868	.3346	.3824
3.875	.05110	.0766	.1022	.1277	.1533	.1788	.2044	.2555	.3066	.3577	.4088
4.000	.0542	.0813	.1084	.1360	.1626	.1897	.2168	.2710	.3252	.3794	.4336
4.125	.0578	.0867	.1156	.1445	.1734	.2023	.2312	.2890	.3468	.4046	.4624
4.250	.0614	.0921	.1228	.1535	.1842	.2149	.2456	.3070	.3684	.4298	.4912
4.375	.06508	.0976	.1302	.1627	.1952	.2278	.2603	.3254	.3905	.4556	.5207
4.500	.06885	.1033	.1378	.1722	.2066	.2410	.2755	.3444	.4131	.4820	.5508
4.625	.07273	.1091	.1454	.1818	.2182	.2545	.2909	.3636	.4364	.5091	.5818
4.750	.07672	.1151	.1534	.1918	.2302	.2685	.3069	.3836	.4603	.5370	.6138
4.875	.0808	.1212	.1616	.2020	.2424	.2828	.3232	.4040	.4848	.5656	.6464
5.000	.0850	.1275	.1700	.2125	.2550	.2975	.3400	.4250	.5100	.5950	.6800
5.250	.09371	.1405	.1874	.2343	.2811	.3279	.3748	.4685	.5622	.6560	.7497
5.500	.10286	.1542	.2057	.2571	.3086	.3600	.4114	.5143	.6171	.7200	.8228
5.750	.11242	.1686	.2248	.2810	.3372	.3934	.4496	.5621	.6745	.7869	.8993
6.000	.12241	.1836	.2448	.3061	.3672	.4284	.4896	.6121	.7345	.8569	.9793
6.250	.13282	.1992	.2656	.3321	.3984	.4648	.5313	.6641	.7969	.9297	1.0625
6.500	.14366	.2155	.2873	.3593	.4310	.5028	.5746	.7183	.8620	1.0056	1.1493
6.750	.15492	.2324	.3098	.3873	.4647	.5422	.6197	.7746	.9295	1.0845	1.2393
7.000	.16660	.2499	.3333	.4166	.4998	.5831	.6666	.8333	.9998	1.1662	1.3328
7.250	.17872	.2681	.3574	.4468	.5361	.6255	.7148	.8935	1.0723	1.2510	1.4297
7.500	.19125	.2867	.3825	.4781	.5737	.6694	.7650	.9562	1.1475	1.3387	1.5300
7.750	.20423	.3063	.4084	.5106	.6127	.7148	.8169	1.0212	1.2254	1.4297	1.6337
8.000	.21760	.3264	.4352	.5440	.6538	.7616	.8704	1.0880	1.3056	1.5232	1.7408
8.500	.24566	.3685	.4913	.6141	.7370	.8598	.9826	1.2283	1.4738	1.7196	1.9653
9.000	.27540	.4131	.5508	.6885	.8262	.9639	1.1016	1.3770	1.6525	1.9278	2.2033

$$\text{Displacement} = \frac{\text{Plunger area x stroke}}{231}$$

LEATHER BELTING

The power which a belt is capable of transmitting depends upon its speed, its width, its thickness, and its arc of contact with the smaller pulley. Belt drives for centrifugal pumps should be selected for capacities 20 to 30% higher than that actually required. Data on belt drive are based on arc of contact of 180 deg. Where the actual arc of contact varies from this, the power transmitted should be multiplied by the following factors:

For arc of contact (deg.)	=	130	140	150	160	170	180
Factor..................	=	0.83	0.87	0.91	0.94	0.97	1.00

Belt speeds should never exceed 5500′ per minute and the most economical and satisfactory speeds are between 4000 and 4500′ per minute. Data are based on cast iron pulleys. Where other pulleys are used, the following approximate ratios will apply on the transmitting capacities:

Split wood..............................	90–95%
Soft wood rim	100%
Split steel.............................	105–110%
Paper...................................	110–115%
Leather covered.........................	125%

To insure better service and long life of leather belts, certain minimum pulley diameters are adhered to in good practice:

MINIMUM PULLEY DIAMETER FOR LEATHER BELTS

Single leather belt	Min pulley dia Belt width under 8″	Min pulley dia Belt width over 8″	Double leather belt	Min pulley dia Belt width under 8″	Min pulley dia Belt width over 8″	Three-ply leather belt	Min pulley dia Belt width under 8″	Min pulley dia Belt width over 8″
....	..	..	light......	6″	8″	....	..	...
medium...	3″	5″	medium...	8″	10″	medium...	20″	24″
heavy.....	5″	7″	heavy.....	12″	14″	heavy.....	24″	30″

The following formulae will apply:

Diameter of Driven Pulley

$$d_2 = \frac{d_1 \times r\ p\ m_1}{r\ p\ m_2}$$

Diameter of Driving Pulley

$$d_1 = \frac{d_2 \times r\ p\ m_2}{r\ p\ m_1}$$

These formulae do not take into account the effect of belt thickness or slippage.

Belt speed

$$f\ p\ m = \frac{d \times 3.14 \times r\ p\ m}{12}$$

Horsepower which leather belting will transmit

$$h\ p = \frac{C \times w \times f\ p\ m}{33{,}000}$$

where d_1 is diameter of driving pulley in inches
$r\ p\ m_1$ is speed of driving pulley
d_2 is diameter of driven pulley in inches
$r\ p\ m_2$ is speed of driven pulley
$f\ p\ m$ is feet per minute
w is width in inches
C is constant from following table

Values of "C" based on 180 deg. Arc.

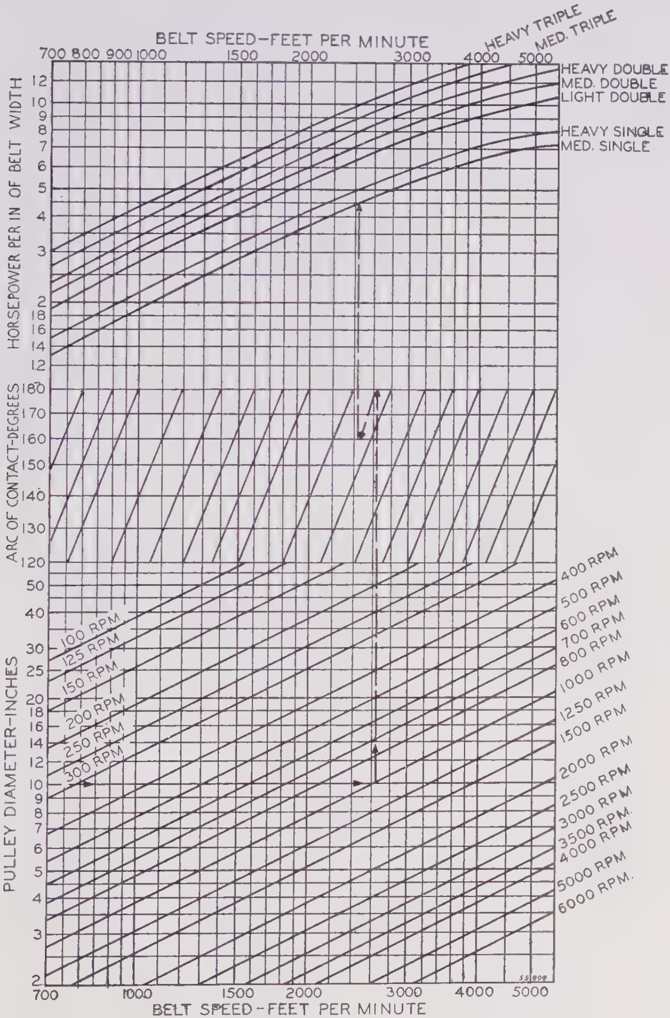
	Single Belt	Double Belt	Three-Ply Belt
Light	47	75	93
Medium	53	83	105
Heavy	58	93	116

The chart labeled "Transmission of h p by Leather Belting" provides a graphic solution for all belt problems.

EXAMPLE OF USE OF CHART (Page 227)

Given a 10″ pulley running at 1000 r p m with a 160° arc of contact and single leather belt; to find the width of belt required to transmit 20 hp. Starting at the pulley diameter of 10″ read horizontally to the intersection of the 1000 r p m diagonal; then vertically to the intersection of the 180° horizontal. By following down the diagonal to the 160° line, correction is made for the reduced arc of contact. Then reading vertically to the intersection of the single belt curve and horizontally to the scale, a value of approxmiately 4.5 hp per in width is obtained. To transmit 20 hp a belt 4½ or 5 in wide would be required.

Transmission of Horsepower by Leather Belting



V-Belt Drives

Recommended V-Belt Cross-Sections for Various Horsepowers and Speeds

Horsepower	MOTOR SPEED—RPM						
	1750	1160	870	690	575	490	435
½	A	A	A	....	....	....	....
¾	A	A	A	....	....	....	....
1	A	A	A	....	....	....	....
1½	A	A	A	....	....	....	....
2	A	A	A	....	....	....	....
3	A	A	B (or A)	....	....	....	....
5	B (or A)	B (or A)	B	....	....	....	....
7½	B	B	B	....	....	....	....
10	B	B	B or C	....	....	....	....
15	B	B or C	C (or B)	....	....	....	....
20	B or C	C (or B)	C	D	D	....	....
25	C (or B)	C	C	D	D	....	....
30	C	C	C	D	D	....	....
40	C	C or D	C or D	D	D	....	....
50	C	C or D	C or D	D	D	E	E
60	C	C or D	D (or C)	D	D	E	E
75	C	D (or C)	D	D	D (or E)	E	E
100	C	D	D	D or E	E (or D)	E	E
125	....	D	D	D or E	E (or D)	E	E
150	....	D	D	E (or D)	E	E	E
200	....	D	D	E	E	E	E
250	....	D	D	E	E	E	E
300 and above	....	D	D	E	E	E	E

Hp transmitted by V-Belts based on 180° arc of contact

Veloc in ft Per Min	Cross-Sect A	Cross-Sect B	Cross-Sect. C	Cross-Sect D	Cross-Sect E
	width ½″ thick ⅜″	width 21/32″ thick ½″	width ⅞″ thick ⅝″	width 1¼″ thick ¾″	width 1½″ thick 1″
1000	.9	1.2	3.0	5.5	7.5
1100	1.0	1.3	3.2	6.0	8 2
1200	1.0	1.4	3 4	6.5	8.9
1300	1.1	1.5	3.6	7.0	9.6
1400	1.2	1.6	3.8	7.5	10.3
1500	1.3	1.7	4.0	8.0	11.0
1600	1.4	1 8	4.3	8.4	11.6
1700	1.5	1.9	4.6	8.8	12 2
1800	1.6	2.1	4.9	9.2	12.8
1900	1.6	2.2	5.2	9.6	13.4
2000	1.7	2.3	5.5	10.0	14.0
2100	1.8	2.4	5.7	10.5	14.8
2200	1.9	2.5	5.9	11.0	15.2
2300	1.9	2.6	6.1	11.5	15.8
2400	2.0	2.7	6.3	12.0	16.4
2500	2.1	2.8	6.5	12.5	17.0

V eloc in ft Per Min	Cross-Sect A	Cross-Sect B	Cross-Sect C	Cross-Sect D	Cross Sect-E
	width ½″ thick ⅜″	width 21/32″ thick ½″	width ⅞″ thick ⅝″	width 1¼″ thick ¾″	width 1½″ thick 1″
2600	2.2	2.8	6.7	12.9	17.5
2700	2.2	2.9	6.9	13.3	18.0
2800	2.3	3.0	7.1	13.7	18.5
2900	2.3	3.1	7.3	14.1	19.3
3000	2.4	3.2	7.5	14.5	19.8
3100	2.5	3.3	7.7	14.8	20.0
3200	2 5	3.4	7.9	15.1	20.5
3300	2 5	3.5	8.1	15.4	21.0
3400	2.6	3.6	8.3	15.7	21.3
3500	2.6	3.7	8.5	16.0	21.8
3600	2.7	3.8	8.6	16.3	22.0
3700	2.7	3.9	8.7	16.6	22.8
3800	2.8	4.0	8.8	16.9	23.0
3900	2.8	4.1	8.9	17 2	23.3
4000	2.8	4.2	9.0	17.5	23.5
5000	2.8	4.2	9.0	17.5	23.5

$$\text{No of belts required} = \frac{\text{hp of drive}}{(\text{hp per belt})\left(1 - \frac{.175\,(D-d)}{C}\right)}$$

D = pitch dia of large pulley, in
d = pitch dia of small pulley, in
C = center distance, in

For pump, compressor and blower drives 40% more belting than shown by above formula should be used.

Courtesy of Dayton Rubber Manufacturing Co.

Data Required By Pump Manufacturers For Proper Selection of Material

1. SOLUTION TO BE PUMPED (Give common name, where possible such as "spinning bath," "black liquor," "spent pickle," etc.)..
2. PRINCIPAL CORROSIVES (H_2SO_4, HC1, etc.)..................................% by weight (In case the mixtures, state definite percentages by weight. For example: mixture contains 2% acid, in terms of 96.5% H_2SO_4.)
3. pH (if aqueous solution)..............................at.......................F
4. IMPURITIES OR OTHER CONSTITUENTS NOT GIVEN IN "2" (List amounts of any metallic salts, such as chlorides, sulphates, sulphides, chromates, and any organic materials which may be present, even though in percentages as low as .01%. Indicate, where practical, whether they act as accelerators or inhibitors on the pump material.)..
5. SPECIFIC GRAVITY (solution pumped)................ at.....................F
6. TEMPERATURE OF SOLUTION: Maximum.....F, Minimum.....F, Normal.....F
7. VAPOR PRESSURES AT ABOVE TEMPERATURES: Maximum ...Minimum.... Normal.... (Indicate units used, such as pounds gauge, inches water, millimeters mercury.)
8. VISCOSITY...........SSU; or...........centistokes; at.........................F
9. AERATION: Air-Free .. ..Partial...............Saturated............... Does liquid have tendency to foam?...
10. OTHER GASES IN SOLUTION..........ppm, or........................cc per liter ....
11. SOLIDS IN SUSPENSION: (state types)..
    ....
    Specific gravity of solids...
    Quantity of solids..% by weight
    Particle size.................mesh.................................% by weight
    ....mesh.................................% by weight
    ....mesh.................................% by weight
    Character of solids: Pulpy.......... Gritty.......... Hard.......... Soft..........
12. CONTINUOUS OR INTERMITTENT SERVICE...
    Will pump be used for circulation closed system or for transfer?.....................
    Will pump be operated at times against closed discharge?...........................
    If intermittent, how often is pump started? .... times per....................
    Will pump be flushed and drained when not in service?...............................
13. TYPE OF MATERIAL IN PIPE LINES TO BE CONNECTED TO PUMP........
    If desirable, are insulated joints practical?...
    If so, what percentage of element (Fe, Ni, Cu, etc.) is objectionable?...............
14. IS METAL CONTAMINATION UNDESIRABLE?..
15. PREVIOUS EXPERIENCE Have you pumped this solution previously? ....
    If so, of what material or materials was pump made?................................
    ....
    Service life in months?..
    In case of trouble, what parts were affected?.......................................
    Was trouble primarily due to corrosion?.................erosion?......................
    galvanic action?....................stray current?....................................
    Was attack uniform?................If localized, what parts were involved?..........
    ....
    If galvanic action, name materials involved.......................................
    ....
    If pitted, describe size, shape and location (A sketch will be helpful in an analysis of problem) ....
16. WHAT IS CONSIDERED AN ECONOMIC LIFE?...
    (If replacement does not become too frequent, the use of inexpensive pump materials may be the most economical.)

6

Pump Materials

The accompanying tables are printed as a guide to pump users, indicating the materials commonly used in the manufacture of pumps for the liquid services listed. It must be recognized, however, that temperature, abrasive qualities of the liquid, concentration, purity, and structural design problems are factors that will seriously affect selection of the materials for a pump.

The letter symbols and numerical selections as used in Column 5 "Material Selection" are summerized below.

A — designates an all bronze pump
B — designates a bronze fitted pump
C — designates an all iron pump

SUMMARY OF MATERIALS SELECTIONS AND NATIONAL SOCIETY STANDARDS DESIGNATIONS

Institute Selection No.	Corresponding National Society* Standards Designation			Remarks
	ASTM	ACI	AISI	
1....	A48, Classes 20, 25, 30, 35, 40 & 50	....	....	Gray Iron—six grades
2....	B143, 1B & 2A; B144, 3A; B145, 4A	....	....	Tin Bronze—six grades (includes two grades not covered by ASTM Specifications as explained above under Selection No. 2)
3....	A216, WCB	....	1030	Carbon Steel
4....	A217, C5	....	501	5% Chromium Steel
5....	A296, CA15	CA15	410	13% Chromium Steel
6....	A296, CB30	CB30	....	20% Chromium Steel
7....	A296, CC50	CC50	446	28% Chromium Steel
8....	A296, CF-8	CF-8	304	18-8 Austenitic Steel
9....	A296, CF-8M	CF-8M	316	18-8 Molybdenum Austenitic Steel
10....	....	CN-7M	....	A series of highly-alloyed steels normally used where the corrosive conditions are severe
11....	....	....	....	A series of nickel-base alloys
12....	....	....	....	High-silicon cast iron
13....	....	....	....	Austenitic cast iron
14....	....	....	....	Monel metal
15....	....	....	....	Nickel

* ASTM—denotes American Society for Testing Materials
ACI—denotes Alloy Casting Institute
AISI—denotes American Iron and Steel Institute

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Materials of Construction For Pumping Various Liquids

Column 1 Liquid	Column 2 Condition of Liquid	Column 3 Chemical Symbol	Column 4 Specific Gravity	Column 5 Material Selection
Acetaldehyde		C_2H_4O	0.78	C
Acetate Solvents				A, B, C, 8, 9, 10, 11
Acetone		C_3H_6O	0.79	B, C
Acetic Anhydride		$C_4H_6O_3$	1.08	8, 9, 10, 11, 12
Acid, Acetic	Conc. Cold	$C_2H_4O_2$	1.05	8, 9, 10, 11, 12
Acid, Acetic	Dil. Cold			A, 8, 9, 10, 11, 12
Acid, Acetic	Conc. Boiling			9, 10, 11, 12
Acid, Acetic	Dil. Boiling			9, 10, 11, 12
Acid, Arsenic, Ortho-		$H_3AsO_4 \frac{1}{2}H_2O$	2.0–2.5	8, 9, 10, 11, 12
Acid, Benzoic		$C_7H_6O_2$	1.27	8, 9, 10, 11
Acid, Boric	Aqueous Sol.	H_3BO_3		A, 8, 9, 10, 11, 12
Acid, Butyric	Conc.	$C_4H_8O_2$	0.96	8, 9, 10, 11
Acid, Carbolic	Conc. (M. P. 106 F)	C_6H_6O	1.07	C, 8, 9, 10, 11
Acid, Carbolic	(See Phenol)			B, 8, 9, 10, 11
Acid, Carbonic	Aqueous Sol.	CO_2+H_2O		A
Acid, Chromic	Aqueous Sol.	$Cr_2O_3+H_2O$		8, 9, 10, 11, 12
Acid, Critic	Aqueous Sol.	$C_6H_8O_7+H_2O$		A, 8, 9, 10, 11, 12
Acids, Fatty (Oleic, Palmitic, Stearic, etc.)				A, 8, 9, 10, 11
Acid, Formic		CH_2O_2	1.22	9, 10, 11
Acid, Fruit				A, 8, 9, 10, 11, 14
Acid, Hydrochloric	Coml. Conc.	HCl	1.19 (38%)	11, 12
Acid, Hydrochloric	Dil. Cold			10, 11, 12, 14, 15
Acid, Hydrochloric	Dil. Hot			11, 12
Acid, Hydrocyanic		HCN	0.70	C, 8, 9, 10, 11
Acid, Hydrofluoric	Anhydrous, with Hydro Carbon	$HF+HxCx$		3, 14
Acid, Hydrofluoric	Aqueous Sol.	HF		A, 14
Acid, Hydrofluosilicic		$H\ SiF_6$	1.30	A, 14
Acid, Lactic		$C_3H_6O_3$	1.25	A, 8, 9, 10, 11, 12
Acid, Mine Water				A, 8, 9, 10, 11
Acid, Mixed	Sulfuric — Nitric			C, 3, 8, 9, 10, 11, 12
Acid, Muriatic	(See Acid, Hydrochloric)			

6

Materials of Construction For Pumping Various Liquids

Column 1 Liquid	Column 2 Condition of Liquid	Column 3 Chemical Symbol	Column 4 Specific Gravity	Column 5 Material Selection
Acid, Naphthenic	....	....	....	C, 5, 8, 9, 10, 11
Acid, Nitric	Conc. Boiling	HNO_3	1.50	6, 7, 10, 12
Acid, Nitric	Dilute	....	....	5, 6, 7, 8, 9, 10, 12
Acid, Oxalic	Cold	$C_2H_2O_4 . 2H_2O$	1.65	8, 9, 10, 11, 12
Acid, Oxalic	Hot	$C_2H_2O_4 . 2H_2O$	....	10, 11, 12
Acid, Ortho-Phosphoric	....	H_3PO_4	1.87	9, 10, 11
Acid, Pictric	....	$C_6H_3N_3O_7$	1.76	8, 9, 10, 11, 12
Acid, Pyrogallic	....	$C_6H_6O_3$	1.45	8, 9, 10, 11
Acid, Pyroligneous	....	....	....	A, 8, 9, 10, 11
Acid, Sulfuric	$>77\%$ Cold	H_2SO_4	1.69–1.84	C, 10, 11, 12
Acid, Sulfuric	$65/93\% > 175$ F	....	....	11, 12
Acid, Sulfuric	$65/93\% < 175$ F	....	....	10, 11, 12
Acid, Sulfuric	10–65%	....	....	10, 11, 12
Acid, Sulfuric	$<10\%$	....	....	A, 10, 11, 12, 14
Acid, Sulfuric (Oleum)	Fuming	$H_2SO_4+SO_3$	1.92–1.94	3, 10, 11
Acid, Sulfurous	....	H_2SO_3	....	A, 8, 9, 10, 11
Acid, Tannic	....	$C_{14}H_{10}O_0$	....	A, 8, 9, 10, 11, 14
Acid, Tartaric	Aqueous Sol.	$C_4H_6O_6 . H_2O$	....	A, 8, 9, 10, 11, 14
Alcohols	....	....	....	A, B
Alum	See Aluminum Sulphate and Potash Alum)........		....	....
Aluminum Sulphate	Aqueous Sol.	$Al_2(SO_4)_3$	....	10, 11, 12, 14
Ammonia, Aqua	....	NH_4OH	....	C
Ammonium Bicarbonate	Aqueous Sol.	NH_4HCO_3	....	C
Ammonium Chloride	Aqueous Sol.	NH_4Cl	....	9, 10, 11, 12, 14
Ammonium Nitrate	Aqueous Sol.	NH_4NO_3	....	C, 8, 9, 10, 11, 14
Ammonium Phosphate, Dibasic	Aqueous Sol.	$(NH_4)_2HPO_4$	....	C, 8, 9, 10, 11, 14
Ammonium Sulfate	Aqueous Sol.	$(NH_4)_2SO_4$	....	C, 8, 9, 10, 11
Ammonium Sulfate	With sulfuric acid	....	....	A, 9, 10, 11, 12
Aniline	....	C_6H_7N	1.02	B, C
Aniline Hydrochloride	Aqueous Sol.	$C_6H_5NH_2HCl$	....	11, 12
Asphalt	Hot	....	0.98–1.4	C, 5
Barium Chloride	Aqueous Sol.	$BaCl_2$	....	C, 8, 9, 10, 11

Materials of Construction For Pumping Various Liquids

Column 1	Column 2	Column 3	Column 4	Column 5
Liquid	**Condition of Liquid**	**Chemical Symbol**	**Specific Gravity**	**Material Selection**
Barium Nitrate	Aqueous Sol.	$Ba(NO_3)_2$		C, 8, 9, 10, 11
Beer				A, 8
Beer Wort				A, 8
Beet Juice				A, 8
Beet Pulp				A, B, 8, 9, 10, 11
Benzene		C_6H_6	0.88	
Benzine	(See Petroleum ether)			
Benzol	(See Benzene)			B, C
Bichloride of Mercury	(See Mercuric Chloride)			
Black Liquor	(See Liquor, Pulp Mill)			
Bleach Solutions	(See type)			
Blood				A, B
Boiled Feedwater	(See Water, Boiler Feed)			
Brine, Calcium Chloride	pH>8	$CaCl_2$		C
Brine, Calcium Chloride	pH<8			A, 10, 11, 13, 14
Brine, Calcium & Magnesium Chlorides	Aqueous Sol.			A, 10, 11, 13, 14
Brine, Calcium & Sodium Chloride	Aqueous Sol.			A, 10, 11, 13, 14
Brine Sodium Chloride	Under 3% Salt, Cold	NaCl		A, C, 13
Brine, Sodium Chloride	Over 3% Salt, Cold		1.02–1.20	A, 8, 9, 10, 11, 13, 14
Brine, Sodium Chloride	Over 3% Salt, Hot			9, 10, 11, 12, 14
Brine, Sea Water			1.03	A, B, C
Butane		C_4H_{10}	0.60 @ 32 F	B, C, 3
Calcium Bisulfite	Paper Mill	$Ca(HSO\ )_2$	1.06	9, 10, 11
Calcium Chlorate	Aqueous Sol.	$Ca(ClO_3)_2 2H_2O$		10, 11, 12
Calcium Hypochlorite		$Ca(OCl)_2$		C, 10, 11, 12
Calcium Magnesium Chloride	(See Brines)			
Cane Juice				A, B, 13
Carbon Bisulfide		CS_2	1.26	C
Carbonate of Soda	(See Soda Ash)			
Carbon Tetrachloride	Anhydrous	CCl_4	1.50	B, C
Carbon Tetrachloride	Plus Water			A, 8

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Materials of Construction For Pumping Various Liquids

Column 1	Column 2	Column 3	Column 4	Column 5
Liquid	Condition of Liquid	Chemical Symbol	Specific Gravity	Material Selection
Catsup				A, 8, 9, 10, 11
Caustic Potash	(See Potassium Hydroxide)			
Caustic Soda	(See Sodium Hydroxide)			
Cellulose Acetate				9, 10, 11
Chlorate of Lime	(See Calcium Chlorate)			
Chloride of Lime	(See Calcium Hypochlorite)			
Chlorine Water	(Depending on conc.)			9, 10, 11, 12
Chlorobenzene		C_6H_5Cl	1.1	A, B, 8
Chloroform		$CHCl_3$	1.5	A, 8, 9, 10, 11, 14
Chrome Alum	Aqueous Sol.	$CrK(SO_4)_2 . 12H_2O$		10, 11, 12
Condensate	(See Water, Distilled)			
Copperas, Green	(See Ferrous Sulfate)			
Copper Ammonium Acetate	Aqueous Sol.			C, 8, 9, 10, 11
Copper Chloride (Cupric)	Aqueous Sol.	$CuCl_2$		11, 12
Copper Nitrate		$Cu(NO_3)_2$		8, 9, 10, 11
Copper Sulfate, Blue Vitriol	Aqueous Sol.	$CuSO_4$		8, 9, 10, 11, 12
Creosote	(See Oil, Creosote)			
Cresol, Meta		C_7H_8O	1.03	C, 5
Cyanide	(See Sodium Cyanide and	Potassium Cyanide)		
Cyanogen	In Water	$(CN)_2$Gas		C
Diphenyl		$C_6H_5 . C_6H_5$	.99	C, 3
Enamel				C
Ethanol	(See Alcohols)			
Ethylene Chloride (di-chloride)	Cold	$C_2H_4Cl_2$	1.28	A, 8, 9, 10, 11, 14
Ferric Chloride	Aqueous Sol.	$FeCl_3$		11, 12
Ferric Sulphate	Aqueous Sol.	$Fe_2(SO_4)_3$		8, 9, 10, 11, 12
Ferrous Chloride	Cold, Aqueous	$FeCl_2$		11, 12
Ferrous Sulphate (Green) Copperas)	Aqueous Sol.	$FeSO_4$		9, 10, 11, 12, 14
Formaldehyde		CH_2O	1.08	A, 8, 9, 10, 11
Fruit Juices				A, 8, 9, 10, 11, 14
Furfural		$C_5H_4O_2$	1.16	A, C, 8, 9, 10, 11

Materials of Construction For Pumping Various Liquids

Column 1	Column 2	Column 3	Column 4	Column 5
Liquid	Condition of Liquid	Chemical Symbol	Specific Gravity	Material Selection
Gasoline			0.68–0.75	B, C
Glaubers Salt	(See Sodium Sulfate)			
Glucose				A, B
Glue	Hot			B C
Glue Sizing				A
Glycerol (Glycerin)		$C_3H_8O_3$	1.26	A, B, C
Green Liquor)	(See Liquor, Pulp Mill)			
Heptane		C_7H_{16}	0.69	B, C
Hydrogen Peroxide	Aqueous Sol.	H_2O_2		8, 9, 10, 11
Hydrogen Sulfide	Aqueous Sol.	H_2S		8, 9, 10, 11
Hydrosulfite of Soda	(See Sodium Hydrosulfite)			
Hyposulfite of Soda	(See Sodium Thiosulfate)			
Kaolin Slip	Suspension in Water			C, 3
Kaolin Slip	Suspension in Acid			10, 11, 12
Kerosene	(See Oil, Kerosene)			
Lard	Hot			B, C
Lead Acetate (Sugar of Lead)	Aqueous Sol.	$Pb(C_2H_3O_2)_2 . 3H_2O$		9, 10, 11, 14
Lead	Molten			C, 3
Lime Water (Milk of Lime)		$Ca(OH)_2$		C
Liquor—Pulp Mill: Black				C, 3, 9, 10, 11, 12, 14
Liquor—Pulp Mill: Green				C, 3, 9, 10, 11, 12, 14
Liquor—Pulp Mill. White				C, 3, 9, 10, 11, 12, 14
Liquor—Pulp Mill: Pink				C, 3, 9, 10, 11, 12, 14
Liquor—Pulp Mill. Sulfite				9, 10, 11
Lithium Chloride	Aqueous Sol.	LiCl		C
Lye, Caustic	(See Potassium & Sodium	Hydroxide)		
Magnesium Chloride	Aqueous Sol.	$MgCl_2$		10, 11, 12
Magnesium Sulfate (Epsom Salts	Aqueous Sol.	$MgSO_4$		C, 8, 9, 10, 11
Manganese Chloride	Aqueous Sol.	$MnCl_2 . 4H_2O$		A, 8, 9, 10, 11, 12
Manganous Sulfate	Aqueous Sol.	$MnSO_4 . 4H_2O$		A, C, 8, 9, 10, 11
Mash				A, B, 8
Mercuric Chloride	Very Dilute Aqueous Sol.	$HgCl_2$		9, 10, 11, 12

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Materials of Construction For Pumping Various Liquids

Column 1	Column 2	Column 3	Column 4	Column 5
Liquid	Condition of Liquid	Chemical Symbol	Specific Gravity	Material Selection
Mercuric Chloride	Coml. Conc. Aqueous Sol.	$HgCl_2$	...	11, 12
Mercuric Sulfate	In Sulfuric Acid	$HgSO_4+H_2SO_4$	...	10, 11, 12
Mercurous Sulfate	In Sulfuric Acid	$Hg_2SO_4+H_2SO_4$	...	10, 11, 12
Methyl Chloride	...	CH_3Cl	0.52	C
Methylene Chloride	...	CH_2Cl_2	1.34	C, 8
Milk	...	...	1.03–1.04	8
Milk of Lime	(See Lime Water)	...	...	...
Mine Water	(See Acid, Mine Water)	...	...	...
Miscella	(20% Soyabean Oil & Solvent)	...	0.75	C
Molasses	...	...	...	A, B
Mustard	...	...	...	A, 8, 9, 10, 11, 12
Naphtha	...	...	0.78–0.88	B, C
Naphtha, Crude	...	...	0.92–0.95	B, C
Nicotine Sulfate	...	$(C_{10}H_{14}N_2)2H_2SO_4$	...	10, 11, 12, 14
Nitre	(See Potassium Nitrate)	...	...	...
Nitre Cake	(See Sodium Bisulphate)	...	...	...
Nitre Ethane	...	$C_2H_5NO_2$	1.04	B, C
Nitro Methane	...	CH_3NO_2	1.14	B, C
Oil Coal Tar	...	...	...	B, C, 8, 9, 10, 11
Oil, Coconut	...	...	0.91	A, B, C, 8, 9, 10, 11, 14
Oil, Creosote	...	...	1.04–1.10	B, C
Oil, Crude	Cold	...	...	B, C
Oil, Crude	Hot	...	...	3
Oil, Essential	...	...	...	A, B, C
Oil, Fuel	...	...	...	B, C
Oil, Kerosene	...	...	...	B, C
Oil, Linseed	...	...	0.94	A, B, C, 8, 9, 10, 11, 14
Oil, Lubricating	...	...	...	B, C
Oil, Mineral	...	...	...	B, C
Oil, Olive	...	...	0.90	B, C
Oil, Palm	...	...	0.90	A, B, C, 8, 9, 10, 11, 14
Oil, Quenching	...	...	0.91	B, C

Materials of Construction For Pumping Various Liquids

Column 1 Liquid	Column 2 Condition of Liquid	Column 3 Chemical Symbol	Column 4 Specific Gravity	Column 5 Material Selection
Oil, Rapeseed	...	...	0.92	A, 8, 9, 10, 11, 14
Oil, Soya Bean	...	...	...	A, B, C, 8, 9, 10, 11, 14
Oil, Turpentine	...	...	0.87	B, C
Paraffin	Hot	...	...	B, C
Perhydrol	(See Hydrogen Peroxide)	...	...	...
Peroxide of Hydrogen	(See Hydrogen Peroxide)	...	...	...
Petroleum Ether	...	...	...	B, C
Phenol	...	C_6H_6O	1.07	...
Pink Liquor	(See Liquor, Pulp Mill)	...	...	...
Photographic Developers	...	...	...	9, 8, 10, 11
Plating Solutions	(Varied and complicated, consult pump mfgrs.)	...	...	...
Potash	Plant Liquor	...	...	A, 8, 9, 10, 11, 13, 14
Potash Alum	Aqueous Sol.	$Al_2(SO_4)_3K_2SO_4.24H_2O$	...	A, 9, 10, 11, 12, 13, 14
Potassium Bichromate	Aqueous Sol.	$K_2Cr_2O_7$	...	C
Potassium Carbonate	Aqueous Sol.	K_2CO_3	...	C
Potassium Chlorate	Aqueous Sol.	$KClO_3$	...	8, 9, 10, 11, 12
Potassium Chloride	Aqueous Sol.	KCl	...	A, 8, 9, 10, 11, 14
Potassium Cyanide	Aqueous Sol.	KCN	...	C
Potassium Hydroxide	Aqueous Sol.	KOH	...	C, 5, 8, 9, 10, 11, 13, 14, 15
Potassium Nitrate	Aqueous Sol.	KNO_3	...	C, 5, 8, 9, 10, 11
Potassium Sulfate	Aqueous Sol.	K_2SO_4	...	A, 8, 9, 10, 11
Propane	...	C_3H_8	0.59 @ 48 F	B, C, 3
Pyridine	...	C_5H_5N	0.98	C
Pyridine Sulphate	...	...	...	10, 12
Rhidolene	...	...	...	B
Rosin (Colophony)	Paper Mill	...	...	C
Sal Ammoniac	(See Ammonium Chloride)	...	...	...
Salt Lake	Aqueous Sol.	Na_2SO_4—impurities	...	A, 8, 9, 10, 11, 12
Salt Water	(See Brines)	...	...	...
Sea Water	(See Brines)	...	...	...
Sewage	...	...	...	A, B, C
Shellac	...	...	...	A
Silver Nitrate	Aqueous Sol.	$AgNO_3$	...	8, 9, 10, 11, 12

Materials of Construction For Pumping Various Liquids

Column 1 Liquid	Column 2 Condition of Liquid	Column 3 Chemical Symbol	Column 4 Specific Gravity	Column 5 Material Selection
Slop, Brewery	...	...	...	A, B, C
Slop, Distillers	...	...	...	A, 8, 9, 10, 11
Soap Liquor	...	...	...	C
Soda Ash	Cold	Na_2CO_3	...	C
Soda Ash	Hot	...	...	8, 9, 10, 11, 13, 14
Sodium Bicarbonate	Aqueous Sol.	$NaHCO_3$	...	C, 8, 9, 10, 11, 13
Sodium Bisulfate	Aqueous Sol.	$NaHSO_4$	...	10, 11, 12
Sodium Carbonate	(See Soda Ash)	...	...	...
Sodium Chlorate	Aqueous Sol.	$NaClO_3$	...	8, 9, 10, 11, 12
Sodium Chloride	(See Brines)	...	...	...
Sodium Cyanide	Aqueous Sol.	$NaCN$	...	C
Sodium Hydroxide	Aqueous Sol.	$NaOH$	...	C, 5, 8, 9, 10, 11, 13, 14, 15
Sodium Hydrosulfite	Aqueous Sol.	$Na_2S_2O_4 . 2H_2O$	...	8, 9, 10, 11
Sodium Hypochlorite	...	$NaOCl$	...	10, 11, 12
Sodium Hyposulfite	(See Sodium Thisoulfate)	...	...	...
Sodium Meta Silicate	...	...	...	C
Sodium Nitrate	Aqueous Sol.	$NaNO_3$	...	C, 5, 8, 9, 10, 11
Sodium Phosphate: Monobasic	Aqueous Sol.	$NaH_2PO_4\ H_2O$	...	A, 8, 9, 10, 11
Sodium Phosphate: Dibasic	Aqueous Sol.	$Na_2HPO_4 . {}_7H_2O$	...	A, C, 8, 9, 10, 11
Sodium Phosphate: Tribasic	Aqueous Sol.	$Na_3PO4 . {}_2H_2O$	...	C
Sodium Phosphate: Meta	Aqueous Sol.	$Na_4P_4O_{12}$	...	A, 8, 9, 10, 11
Sodium Phosphate: Hexameta	Aqueous Sol.	$(NaPO_3)_6$	...	8, 9, 10, 11
Sodium Plumbite	Aqueous Sol.	...	...	C
Sodium Sulfate	Aqueous Sol.	Na_2SO_4	...	A, 8, 9, 10, 11
Sodium Sulfide	Aqueous Sol.	Na_2S	...	C, 8, 9, 10, 11
Sodium Sulfite	Aqueous Sol.	Na_2SO_3	...	A, 8, 9, 10, 11
Sodium Thiosulfate	Aqueous Sol.	$Na_2S_2O_3 . 5H_2O$	...	8, 9, 10, 11
Stannic Chloride	Aqueous Sol.	$SnCl_4$	...	11, 12
Stannous Chloride	Aqueous Sol.	$SnCl_2$	...	11, 12
Starch	...	$(C_6H_{10}O_5)x$	...	A, B
Strontium Nitrate	Aqueous Sol.	$Sr(NO_3)_2$	...	C, 8
Sugar	Aqueous Sol.	...	...	A, 8, 9, 10, 11, 13

Materials of Construction For Pumping Various Liquids

Column 1	Column 2	Column 3	Column 4	Column 5
Liquid	**Condition of Liquid**	**Chemical Symbol**	**Specific Gravity**	**Material Selection**
Sulfite Liquor	(See Liquor, Pulp Mill)	....	....	....
Sulfur	In Water	S	....	A, C, 8, 9, 10, 11
Sulfur	Molten	S	....	C
Sulfur Chloride	Cold	S_2Cl_2	....	C
Syrup	(See Sugar)	....	....	....
Tallow	Hot	....	0.90	C
Tanning Liquors	....	....	....	A, 8, 9, 10, 11, 12, 14
Tar	Hot	....	....	C, 3
Tar & Ammonia	In Water	....	....	C
Tetrachloride of Tin	(See Stannic Chloride)	....	....	....
Tetraethyl Lead	....	$Pb(C_2H_5)_4$	1.66	B, C
Toluene (Toluol)	....	C_7H_8	0.87	B, C
Trichloroethylene	....	C2HCl3	1.47	A, B, C, 8
Urine	....	....	....	A, 8, 9, 10, 11
Varnish	....	....	....	A, B, C, 8, 14
Vegetable Juices	....	....	....	A, 8, 9, 10, 11, 14
Vinegar	....	....	....	A, 8, 9, 10, 11, 12
Vitriol, Blue	(See Copper Sulfate)	....	....	....
Vitriol, Green	(See Ferrous Sulfate)	....	....	....
Vitriol, Oil of	(See Acid, Sulfuric)	....	....	....
Vitriol, White	(See Zinc Sulfate)	....	....	....
Water, Boiler Feed High Makeup	Not evaporated pH>8.5	....	1.00	C
	pH<8.5	....	....	B
Low Makeup	Evaporated, any pH	....	1.66	4, 5, 8, 14
Water, Distilled	High Purity	....	0.87	A, 8
Water, Distilled	Condensate	....	....	A, B
Water, Fresh	....	....	1.00	B
Water, Mine	(See Acid, Mine Water)	....	....	....
Water, Salt & Sea	(See Brines)	....	....	....
Whiskey	....	....	....	A, 8

Materials of Construction For Pumping Various Liquids

Column 1	Column 2	Column 3	Column 4	Column 5
Liquid	Condition of Liquid	Chemical Symbol	Specific Gravity	Material Selection
White Liquor	(See Liquor, Pulp Mill)			
White Water	Paper Mill			A, B, C
Wine				A 8
Wood Pulp (Stock)				A, B, C
Wood Vinegar	(See Acid Pyroligneous)			
Wort	(See Beer Wort)			
Xylol (Xylene)		C_8H_{10}	0.87	B, C, 8, 9, 10, 11
Yeast				A, B
Zinc Chloride	Aqueous Sol.	$ZnCl_2$		9, 10, 11, 12
Zinc Sulfate	Aqueous Sol.	$ZnSO_4$		A, 9, 10, 11

MEASUREMENT OF HEAD WITH VARIOUS TYPES OF GAGES

Symbols

(The following symbols apply to Figs. A to H)

h_{dg} = Discharge gage reading in feet of water
h_{sg} = Suction gage reading in feet of water
Z_d = Elevation of discharge gage zero above datum elevation in feet
Z_s = Elevation of suction gage zero above datum elevation in feet (Z_d and Z_s are negative if the gage zero is below the datum elevation)
Y_d = Elevation of discharge gage connection to discharge pipe above datum elevation in feet
Y_s = Elevation of suction gage connection to suction pipe above datum elevation in feet
(Y_d and Y_s are negative if the gage connection to the pipe lies below the datum elevation)
V_d = Average water velocity in discharge pipe at discharge gage connection in ft/sec
V_s = Average water velocity in suction pipe at suction gage connection in ft/sec
h_d = Total discharge head in feet above atmospheric pressure at datum elevation
h_g = Suction or discharge gage reading in feet of mercury
h_s = Total suction head in feet above atmospheric pressure at datum elevation
H = Total pump head in feet
$H = h_d - h_s$
(h_d and h_s are negative if the corresponding pressures at the datum elevation are below the atmospheric pressure)
w_m = Specific weight of mercury, lbs/cu ft
w = Specific weight of liquid pumped, lbs/cu ft
h, Z and V without subscripts apply equally to suction and discharge head measurements.

Datum elevation is at the centerline of horizontal pumps and at the entrance eye of the suction impeller on vertical shaft pumps.

Note:—The word "Water" is used in the following text to represent the liquid being pumped. The provisions are applicable to the pumping of other liquids, such as oil, the gages except mercury gages, containing the same liquid as that being pumped.

Connecting pipe air-filled, to be drained before reading. Water cannot be used in U tube if either h_{dg} or h_{sg} exceeds height of rising loop.

In particular installations, either h_d or h_s may be measured by various types of gages. Figs. D to H illustrate various examples, h_g representing generally the gage reading, applicable to either the discharge gage reading h_{dg} or the suction heading h_{sg}.

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Pages 241-244, courtesy of Hydraulic Institute.

Measurement of Head by Means of Water Gages.

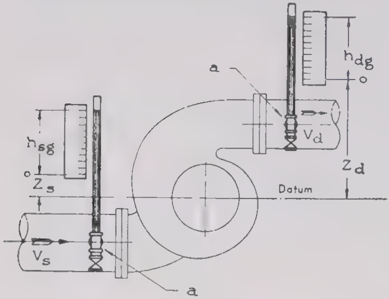


Fig. A

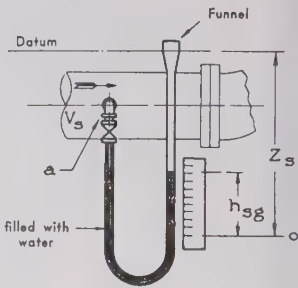


Fig. B

If the pressure at the gage connection "a" is above the atmospheric pressure use arrangement shown in Fig. A with line between discharge or suction pipe and the corresponding gage filled completely with water.

In this case

$$hd = hdg + Zd + \frac{Vd^2}{2g} \qquad hs = hsg + Zs + \frac{Vs^2}{2g}$$

If pressure at gage connection "a" is below atmospheric pressure use arrangement shown in Fig. B showing suction gage.

In this case

$$hs = hsg - Zs + \frac{Vs^2}{2g}$$

The negative sign of Zs indicates that the gage zero is located below the datum.

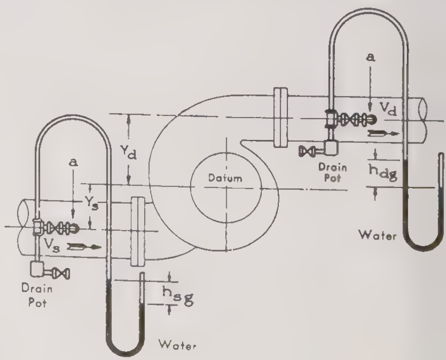
If the pressure at the gage connection "a" is below the atmospheric pressure, use arrangement shown in Fig. C with line between the discharge or suction pipe and the corresponding gage filled completely with air.

In this case

$$hd = -hdg + Yd + \frac{Vd^2}{2g}$$

$$hs = -hsg + Ys + \frac{Vs^2}{2g}$$

Fig. C



Signs of Yd and Ys apply to positions shown in Fig. C.

Measurement of Head by Means of Mercury Gages.

The gage pressure is above the atmospheric pressure and the connection line is filled with liquid pumped. *Arrangement per Fig. D*

In this case

$$h = \frac{Wm}{w} hg + Z + \frac{V^2}{2g}$$

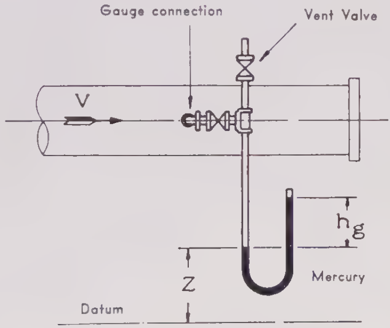


Fig. D

When the gage pressure is below the atmospheric pressure, and the connecting line is completely filled with air, with a rising loop to prevent water from passing to mercury column. *Arrangement per Fig. E.*

In this case

$$h = \frac{Wm}{w} hg + Y + \frac{V^2}{2g}$$

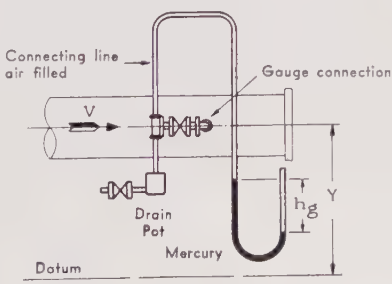


Fig. E.

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Measurement of Total Pump Head by Means of Differential Mercury Gage.

In this case

$$H = \left(\frac{Wm}{w} - 1\right) hg + \frac{Vd^2}{2g} - \frac{Vs^2}{2g}$$

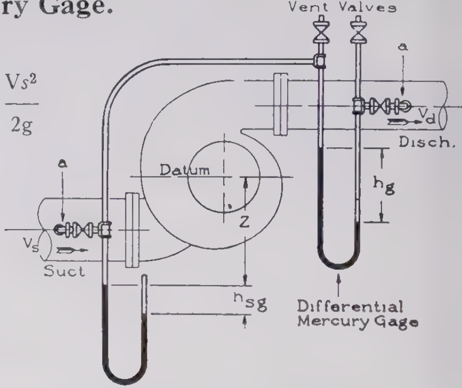

Fig. F

hg—Reading of differential mercury gage in feet of mercury
Connecting lines are completely filled with water.

Besides the differential gage, use a separate suction gage as shown in Figs. B and E.

$$hs = -\frac{Wm}{w} hsg - Z + \frac{Vs^2}{2g}$$

Measurement of Head by Means of Calibrated Bourdon Gages.

The relation between the pressure expressed in pounds per square inch (psi) and that expressed in feet of head is:

Pg = Gage reading, psi
w = Specific weight of the liquid in lbs/cu ft

Z is measured to the center of the gage and is negative if the center of the gage lies below the datum line.

Gage pressure above the atmospheric pressure and the connecting line completely filled with water.

In this case

$$h = \frac{144Pg}{w} + Z + \frac{V^2}{2g}$$

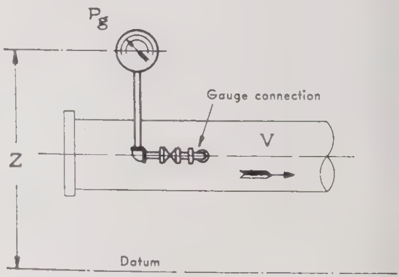

Fig. G

$$\text{Head in ft} = (\text{psi}) \frac{144}{\text{spec weight, lbs/cu ft}}$$

For water at 60°F, 1 psi = 2.31 ft

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